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JSC Research & Technology Report 1998 – 1999

Compiled by the Technology Transfer and Commercialization Office

National Aeronautics
And Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

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JSC Research & Technology Report 1998-1999

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Foreword

NASA is an investment in America's future. As explorers, pioneers, and innovators, we boldly expand frontiers in air and space to inspire and serve America and to benefit the quality of life on Earth.

- NASA Policy Directive 1000.1

As the principle center for NASA's Human Exploration and Development of Space (HEDS) Enterprise, the Johnson Space Center (JSC) leads NASA development of human spacecraft, human support systems, and human spacecraft operations. To implement this mission, JSC has focused on developing the infrastructure and partnerships that enable the technology development for future NASA programs.

In our efforts to develop key technologies, we have found that collaborative relationships with private industry and academia strengthen our capabilities, infuse innovative ideas, and provide alternative applications for our development projects. The American public has entrusted NASA with the responsibility for space technology development, and JSC is committed to the transfer of the technologies that we develop to the private sector for further development and application. It is our belief that commercialization of NASA technologies benefits both American industry and NASA through technology innovation and continued partnering.

To tnis end, we present the 1998-1999 JSC Research and Technology Report. As your guide to the current JSC technologies, this report showcases the projects in work at JSC that may be of interest to U.S. industry, academia, and other government agencies (federal, state, and local). For each project, potential alternative uses and commercial applications are described.

To aid in your search, projects are arranged according to the Major Product Groups used by CorpTech to classify and index types of industry. Some projects fall into multiple categories and are placed under the predominant category, for example, an artificial intelligence project is listed under the Computer Software category, while its function is to automate a process (Automation category). So, take a look through each section to make sure you haven't missed something of interest.

When you find a technology of interest, the JSC Technology Transfer and Commercialization Office is available to assist you in obtaining additional information and for forming a relationship with JSC for utilizing or expanding a technology. Depending on the particular technology, there are possibilities for licensing or sublicensing the technology for your own continued development, entering into Reimbursable Space Act Agreements for the use of unique JSC facilities or capabilities, entering into Non-reimbursable Space Act Agreements for joint development of a technology, and obtaining public domain information including software for use by your business. I urge you to contact the technical point of contact listed

for each project regarding specific technical information on the technology and the Technology Transfer and Commercialization Office for information on the technology transfer process and opportunities. They can be reached at:

Technology Transfer and Commercialization Office
Mail Code HA
NASA Johnson Space Center
Houston, Texas 77058
Phone: (281)483-3809
Fax: (281)244-8452
Email: commercialization1@jsc.nasa.gov
Internet: http://technology.jsc.nasa.gov

Thank you for taking the time to review the JSC technologies. I hope you find an area of mutual interest that we can work together to develop for the future.

George W.S. Abbey
Director, Johnson Space Center

AUTOMATION

Technology Category: Automation

AUT-1 Robonaut: Robotic Astronaut Assistant

Background

The existing International Space Station (ISS) robots (Special Purpose Dexterous Manipulator and Space Station Remote Manipulator System - SSRMS) may not be sufficient for long-term ISS support because they: (1) require additional special alignment targets and grapple fixtures; (2) are too large to fit through tight Extra-Vehicular Activity (EVA) access corridors; and (3) are not capable of the fine motion and dexterous manipulation required to handle small and complex items, soft and flexible materials, and most common EVA interfaces. Furthermore, the teleoperation controls for these robots, which consist of flat panel monitors and joystick-like hand controllers, are not ideal for coordinating the high level of dexterity required for meeting these complex tasks for future missions.

The Robonaut team is designing, developing and now testing a highly dexterous teleoperated system to fill this new niche, augmenting the capabilities of the larger robots, and serving in the role of Astronaut assistant. Key engineering challenges have been design for the space environment, developing a dense packaging of mechanisms and avionics that can equal human scale, designing an arm and hand system that can work with EVA tools, and developing a control system that includes telepresence immersion for human control of the system.

Project Overview

To meet these demanding requirements, the Robonaut system is being developed as an astronaut surrogate capable of performing high-payoff EVA tasks and providing "minuteman" like response for EVA contingencies. The Robonaut concept is centered on an anthropomorphic robot, similar in size to a suited EVA astronaut, and includes two 7 degrees-of-freedom (DOF) arms; two 12 DOF multi-finger robotic hands; a 7 DOF "stinger tail; a 4 DOF stereo camera platform; and an 18 DOF telepresence immersion system for operator tracking.

The robotic arms are capable of dexterous, human-like motion, and are designed to be rugged, safe, and reliable. The robotic hands are designed to handle common EVA tools, such as a handling tool (a.k.a. "ice cream scoop"), to grasp irregularly shaped objects, and to handle a wide spectrum of tasks requiring human-like dexterity. For stabilization, the Robonaut will plug the "stinger tail" into the worksite interface sockets located around the ISS. The Robonaut potentially can be carried by the crew equipment translation aid to various EVA worksites, or can be picked up by the SSRMS for "end-of-arm" tasks. The Robonaut will be teleoperated by a crewperson inside the ISS using telepresence equipment, such as a head-mounted display, tracker sensors, virtual reality gloves, or force-reflective arm and hand masters.

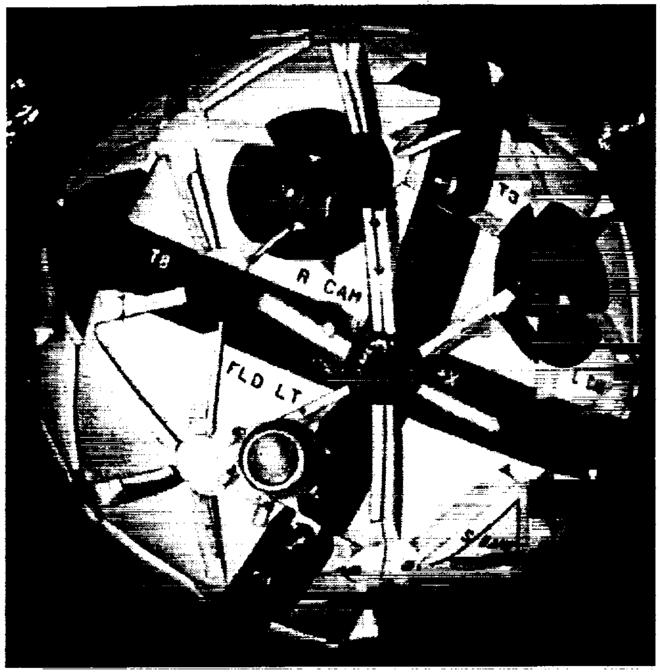
Benefits and Uses

The Robonaut will be very different from its predecessors in both capabilities and operations. By combining advanced dexterous robotics, telepresence, and flight designs, the Robonaut is expected to significantly improve the effectiveness and safety of ISS external operations as well as future Human Exploration and Development of Space missions. This technology is applicable to hazardous material handling, disarming mines and explosives, and in assistive roles such as an arm or hand prothesis.

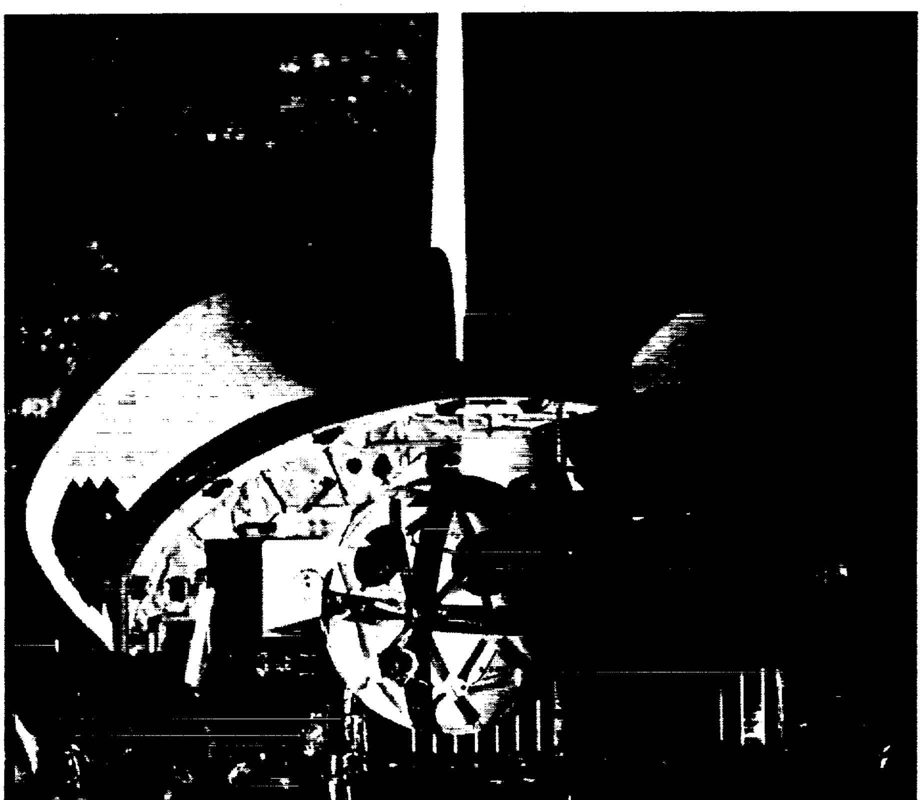
This technology has been disclosed as a new invention and patents are in progress.

For further technical information, contact Dr. Robert Ambrose at (281) 244-5561 or robert.o.ambrose1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

AERCam Sprint Free-flyer



AERCam Sprint on STS-87



Technology Category: Automation

AUT-2 Autonomous Extravehicular Robotic Camera (AERCam)

Background

External views of the Space Shuttle, International Space Station (ISS) and future Lunar/Mars transfer vehicles are desirable to assist onboard crews and ground flight controllers in performing visual inspection associated with assembly, maintenance and servicing tasks. Related non-visual inspection requirements include chemical leak detection, thermal mapping, and structural vibration measurements.

To supplement existing camera infrastructure and develop a versatile positioning system for non-visual sensors, the JSC Automation Robotics and Simulation Division lead the development of the Autonomous Extravehicular Robotic Camera (AERCam), a low-volume, low-mass free-flying camera system. AERCam can be remotely controlled by a crewmember to provide a "bird's eye" view.

Project Overview

The AERCam program began with AERCam Sprint, a 35 pound, 14 inch diameter spherical robot flown as a Space Shuttle flight experiment on STS-87 in December 1997. The 75 minute Sprint test successfully demonstrated the feasibility of teleoperating a free-flying robotic camera in close proximity to the Shuttle and EVA crewmembers. The Sprint flight was followed in March 1998 by an integrated ground demonstration of enhanced AERCam features for autonomous inspections. During the second half of 1998, a conceptual design for an AERCam to support the International Space Station (ISS) was developed that capitalized on technology from the Sprint flight experiment and the subsequent ground demonstration. Culminating in early 1999, a crew evaluation was performed in JSC's Virtual Reality Laboratory (VRL) that generated a set of astronaut recommendations for performing inspection missions with an AERCam free-flyer.

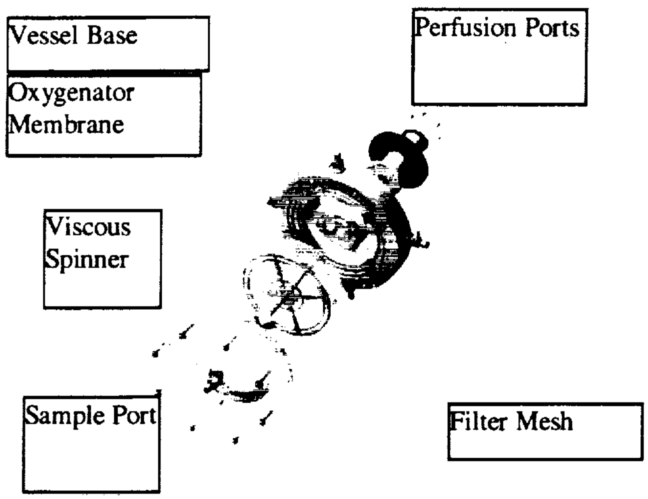
The conceptual design of the ISS AERCam and the results of the VRL crew evaluation form a basis for future in-house or commercial development of an ISS AERCam system.

Benefits and Uses

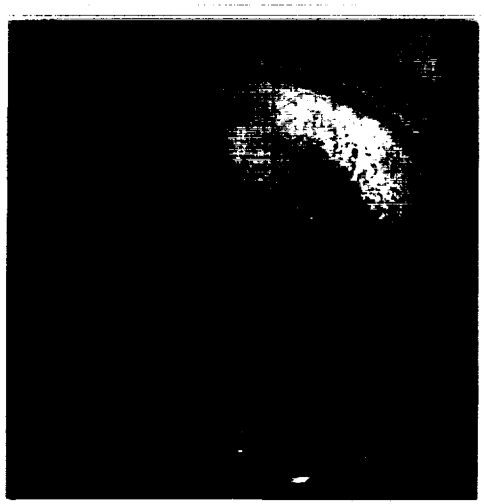
Because AERCam is a free-flyer, it can provide views unobtainable from fixed cameras, cameras on robotic manipulators, or cameras carried by EVA crewmembers. On ISS, for example, AERCam can supplement camera coverage for robotic berthing and maintenance operations. It can enhance EVA productivity by performing visual and non-visual inspections prior to (or in lieu of) EVA, and by relieving EVA crewmembers of "close-out" documentation duties at the end of an EVA.

For further technical information, contact Steven Fredrickson at (281) 483-1457 or steven.e.fredrickson1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

BIOTECHNOLOGY



The **Hydrodynamic Focusing Bioreactor** produces a controllable hydrodynamic focusing force.



En face view of HFB vessel with suspended BHK cells.

Technology Category: Biotechnology

BIO-1 Hydrofocusing Bioreactor

Background

The Johnson Space Center has successfully championed the design, development and operation of space bioreactors to overcome gravity-induced limitations and spawned a unique biotechnology for three-dimensional cell culture and tissue engineering. However, on-orbit formation of air bubbles in the culture fluid, and attempts to remove them from the fluid medium of NASA's rotating wall space bioreactors, degrades both the low-shear culture environment and the delicate three-dimensional tissues. Engineering attempts to resolve this issue with the current space bioreactor have been unsuccessful.

The new Hydrofocusing Bioreactor (HFB), based on the principle of hydrodynamic focusing, was designed to overcome these limitations and to meet both operational and science requirements on orbit. The HFB simultaneously produces a low-shear fluid culture environment and a variable hydrofocusing force that can control the movement, location and removal of suspended cells, tissues and air bubbles from the bioreactor.

Project Overview

The purpose of this biotechnology is to provide a low-shear bioreactor system for long-duration operation in the low-gravity environment aboard orbiting spacecraft. The HFB will support three-dimensional cell culture and tissue engineering in a low-shear fluid environment. It can create hydrodynamic forces to "herd" biological samples and air bubbles to the sampling port for easy removal without degrading the low-shear fluid environment or the delicate samples.

The HFB is a rotating, dome-shaped cell culture vessel with a centrally located sampling port and an internal viscous spinner. The vessel and spinner can rotate at different speeds and in either the same or opposite directions. Rotation of the vessel and viscous interaction at the spinner generate a hydrofocusing force. Adjusting the differential rotation rate between vessel and spinner controls the magnitude of the force.

The HFB has successfully cultured anchorage-dependent and suspension cells, genetically engineered cells, transformed cells, and primary cells. Air bubbles have been successfully "focused" to the central sampling port for removal without degrading the low-shear fluid environment.

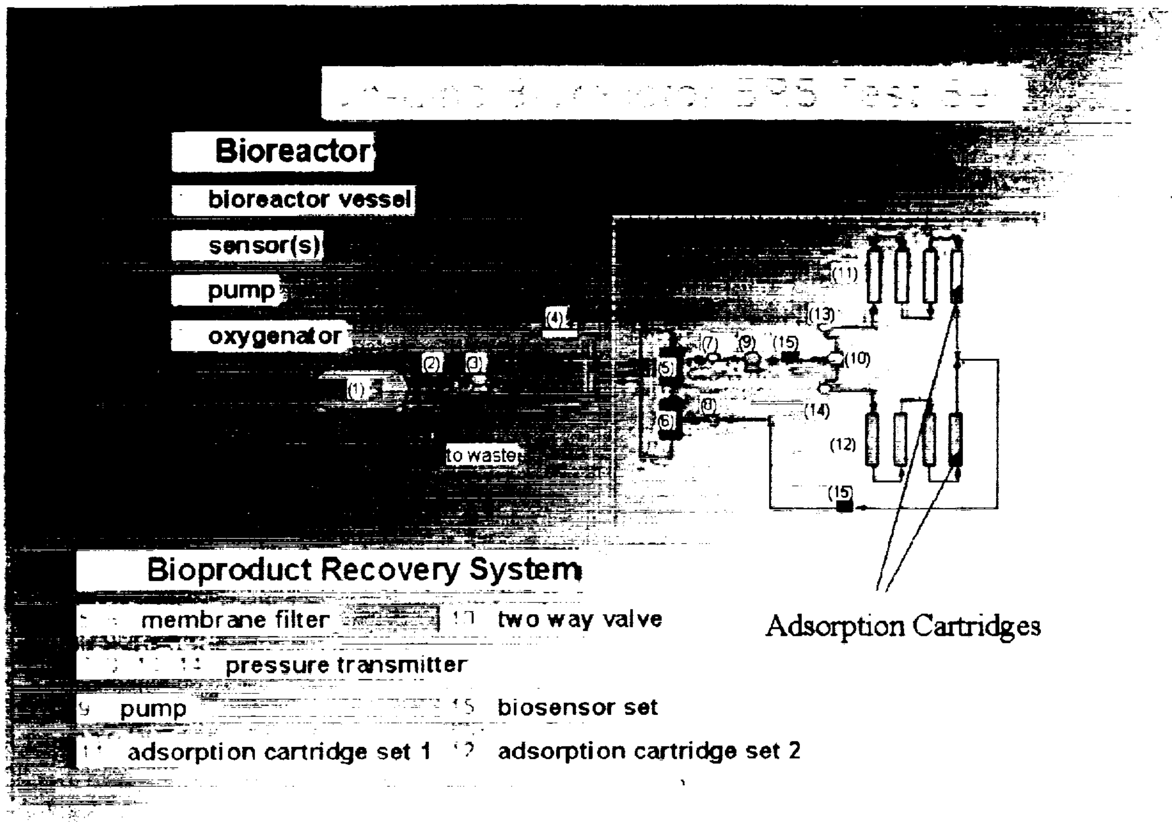
A flight prototype has been built and tested on the KC-135 and will be evaluated on the Space Shuttle. Specific cell culture and tissue engineering experiments will be conducted in the HFB to further characterize the system and to establish a science base line.

Benefits and Uses

The Hydrofocusing Bioreactor is an enabling technology for three-dimensional cell culture and tissue engineering investigations both in laboratories on Earth and on orbiting spacecraft. The use of this new bioreactor technology will open new vistas in our understanding of basic cell function and three-dimensional tissue engineering as they relate to the basis of disease, tissue modeling and drug development. The use of the HFB to support three-dimensional cell culture and tissue engineering has widespread applications in tissue modeling and replacement. The HFB will support cell culture and tissue engineering investigations aboard the ISS in the Biotechnology Facility.

The HFB is currently licensed through Wyle Life Sciences to CelDyne (Houston, Tx).

For further technical information, contact Dr. Steve Gonda at (281) 483-8745 or steven.gonda1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.



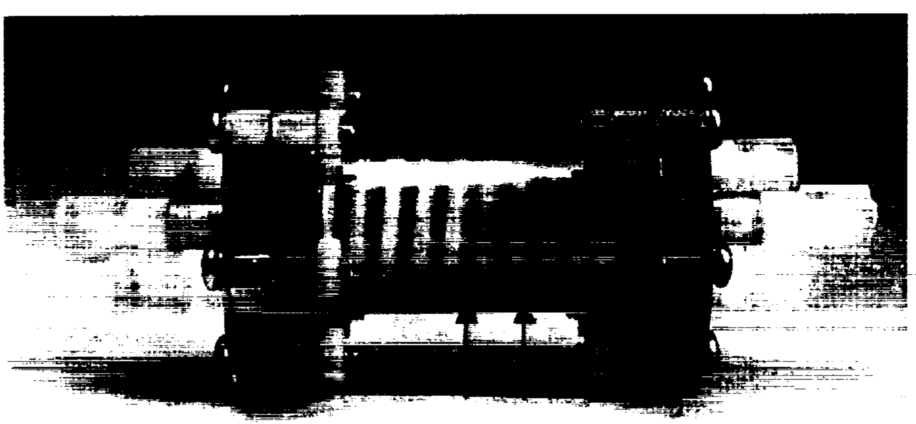


Figure 2. BRS Centrifugal Adsorption Cartridge. Bioproducts are captured as bioreactor fluid flows through specific absorbents (arrows).

Technology Category: Biotechnology

BIO-2 Bioproduct Recovery System

Background

A major focus of the Johnson Space Center Biotechnology Cell Science Program is the development of space bioreactors that can be used aboard spacecraft to overcome gravity-induced limitations in cell culture and tissue engineering. The current generation of space bioreactors can support some aspects of long-duration cell cultures, but cannot be used to separate and preserve or remove bioproducts. Some of the bioactive molecules present in trace quantities in the bioreactors are valuable, while other biomolecules present can act as cell inhibitors and either lead to termination of cellular production of desired molecules or to cell death.

Project Overview

The purpose of this project is to develop a Bioproduct Recovery System (BRS) that allows the selective removal of molecules of interest from space bioreactors. Specifically the BRS is designed to target specific biomolecules or waste products, to continuously adsorb and separate biomolecules from dilute bioreactor effluents, and to stabilize and preserve targeted bioproducts.

The Bioproduct Recovery System is designed as a cartridge system that integrates into the space bioreactor perfusion loop. Culture media from the space bioreactor flows from the perfusion loop into the BRS cartridges, each of which is packed with an adsorbent that selectively binds, separates and retains bioproduct(s) of interest. Each BRS contains several adsorption cartridges that contain specific-affinity adsorbents for targeted biomolecules or waste products. During operation of the bioreactor, as the BRS cartridges become fully saturated with target bioproducts, they can be removed for storage or processed further. Further processing may involve flushing the saturated cartridges with solutions that stabilize the structural integrity and functional activity of the bound bioproducts. The BRS is miniaturized to meet volume and power constraints and to operate in the low gravity environment of space.

The BRS concept revolves around two distinct systems: an on-line system, in which bioreactor media continuously flows through the BRS cartridges, and a downstream system, in which bioreactor spent media flows in a single pass through the BRS cartridges. Each BRS cartridge is packed with a solid phase affinity absorbent that specifically binds the target bioproduct.

The BRS has successfully operated in the range of space bioreactor flow rates and efficiently captured the recombinant protein beta-galactosidase produced in a bioreactor by SF-9 insect cells.

Benefits and Uses

The National Research Council has identified the need for separation and preservation technologies that allow the recovery of high-value biomolecules from dilute aqueous sources, such as bioreactors. The use of the Bioproduct Recovery System on-orbit will enhance the science returns and the commercial potential of long duration experiments in space bioreactors in the BioTechnology Facility on the International Space Station. The Bioproduct Recovery System will also be the basis of an enabling technology for NASA's Human Exploration and Development of Space enterprise for the on-orbit recovery of valuable products from aqueous resources.

This technology has been submitted as a new invention disclosure.

For further technical information, Dr. Steve R. Gonda at (281) 483-8745 or steven.gonda1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

BIO-3 Optical pH Sensor

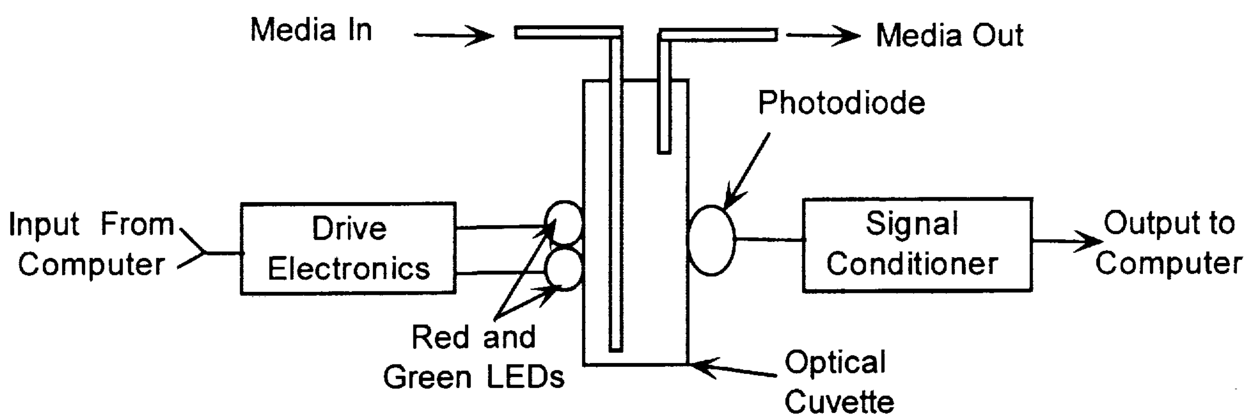


Figure 1. Schematic Diagram of the Optical pH Sensor

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Technology Category: Biotechnology

BIO-3 Optical pH Sensor

Background

Successful operation of space bioreactors depends in part on the monitoring and control of the pH in culture fluids. Measurements of the pH of culture fluids should be conducted without compromising the sterility of the bioreactor and preferably using a non-invasive approach. In short term shuttle missions and long-duration cell culture and tissue engineering investigations in space bioreactors, automated sensor technology is critical to minimizing crew time. A reliable pH sensor satisfying the above requirements was needed to support NASA's goals for long-duration, continuous bioreactor operation in the BioTechnology Facility aboard the International Space Station.

pH sensors based on electrochemical and field effect transistor (FET) technologies are frequently used in commercial biotechnology; however, these sensors need frequent calibration and are difficult to sterilize. The optical pH sensor developed at JSC continuously measures cell culture media pH in a perfused bioreactor system. The measurement is accurate within $\pm$ 0.1 pH unit in the pH range between 6.5 and 7.5 with a single calibration. The principal method used in this technology is the measurement of light absorption characteristics of an organic dye present in the media.

Project Overview

An optical pH sensor was developed to continuously measure the pH of the media in the perfusion loop of the rotating wall bioreactor. The sensor was constructed consisting of a light source, an optical flow cell and internally amplified photodiode. The schematic diagram of the pH sensor is shown in Figure 1. The illumination source is a pair of light emitting diodes (LEDs). Each LED can emit either a green light (wavelength maximum of 558 nm) or red light (wavelength maximum of 625 nm). The flow cell is an optical quality quartz cuvette, which has a self-masking window. The pH sensor measures the light absorption characteristics of an organic dye present in the media and the ratio of the intensity of the transmitted green and red light is correlated to the pH of the solution. The sensor can be sterilized using an autoclave or ethylene oxide in a stand alone as well as complete bioreactor configuration mode.

The non-invasive optical pH sensor developed at JSC was tested with a rotating wall perfused vessel (RWPV) bioreactor system using a baby hamster kidney (BHK-21) cell line for 124 days. A single set of calibration data was used for the pH sensor during the entire 124 day period. The pH as measured by the pH sensor was compared with the pH of the solution measured by a Fiber Optically-coupled Shimadzu Spectrophotometer (FOSS) and Blood Gas Analyzer (BGA). The error in measuring the pH using the pH sensor (as compared to BGA) was $\pm$ 0.1 pH unit.

New generation LEDs with stable light output in the 560 nm region will be used for probe light illumination to improve the technology.

Benefits and Uses

The optical pH sensor can be used to measure the pH of the media in a perfusion loop of bioreactors. These bioreactors are manufactured by Synthecon Inc., Houston and are being extensively used in national and international laboratories.

The sensor technology has been submitted as a new invention disclosure.

For further technical information, contact Antony S. Jeevarajan at (281) 483-4298, antony.s.jeevarajan1@jsc.nasa.gov and Melody M. Anderson at (281) 483-3318, melody.anderson1@jsc.nasa.gov.
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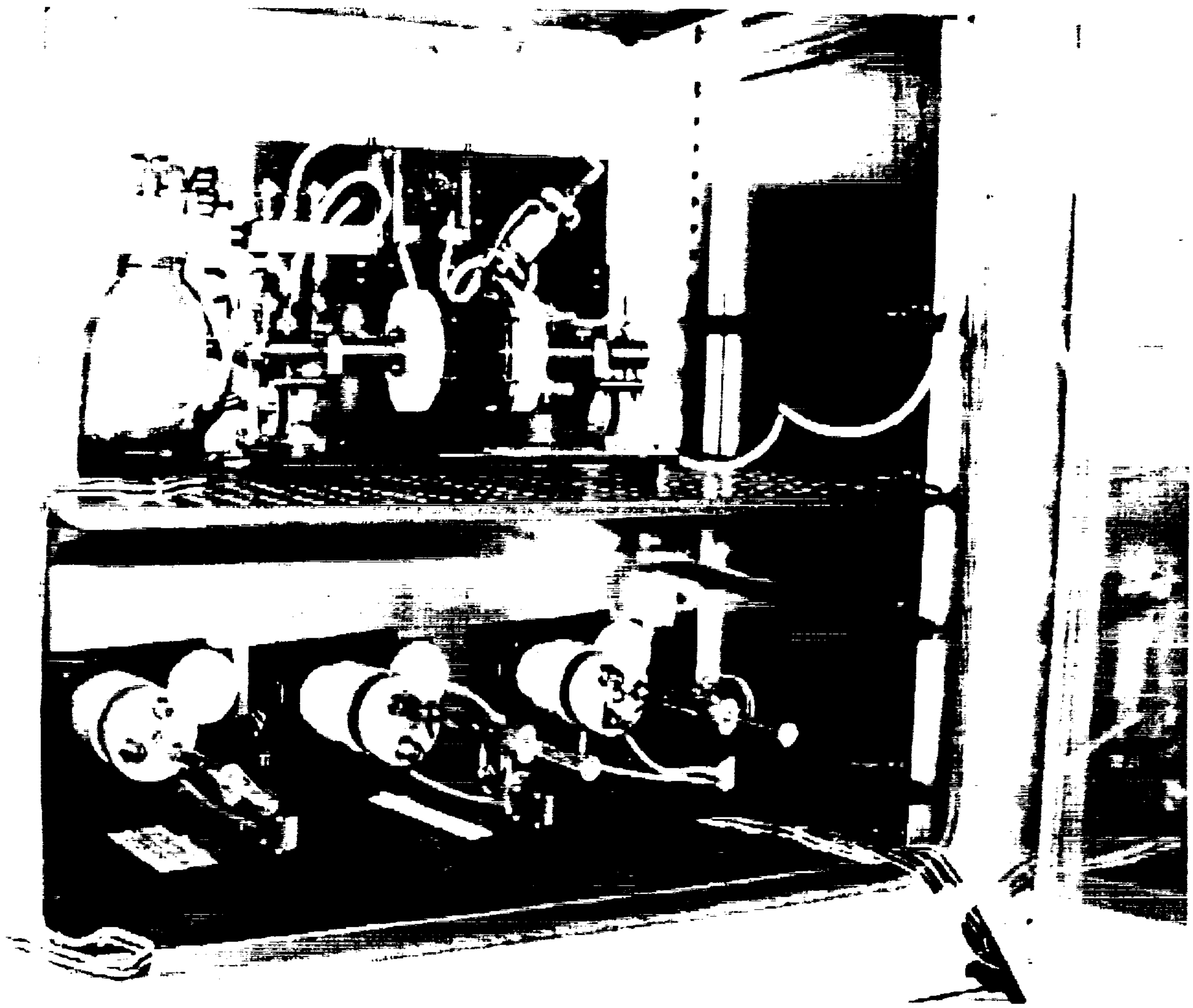

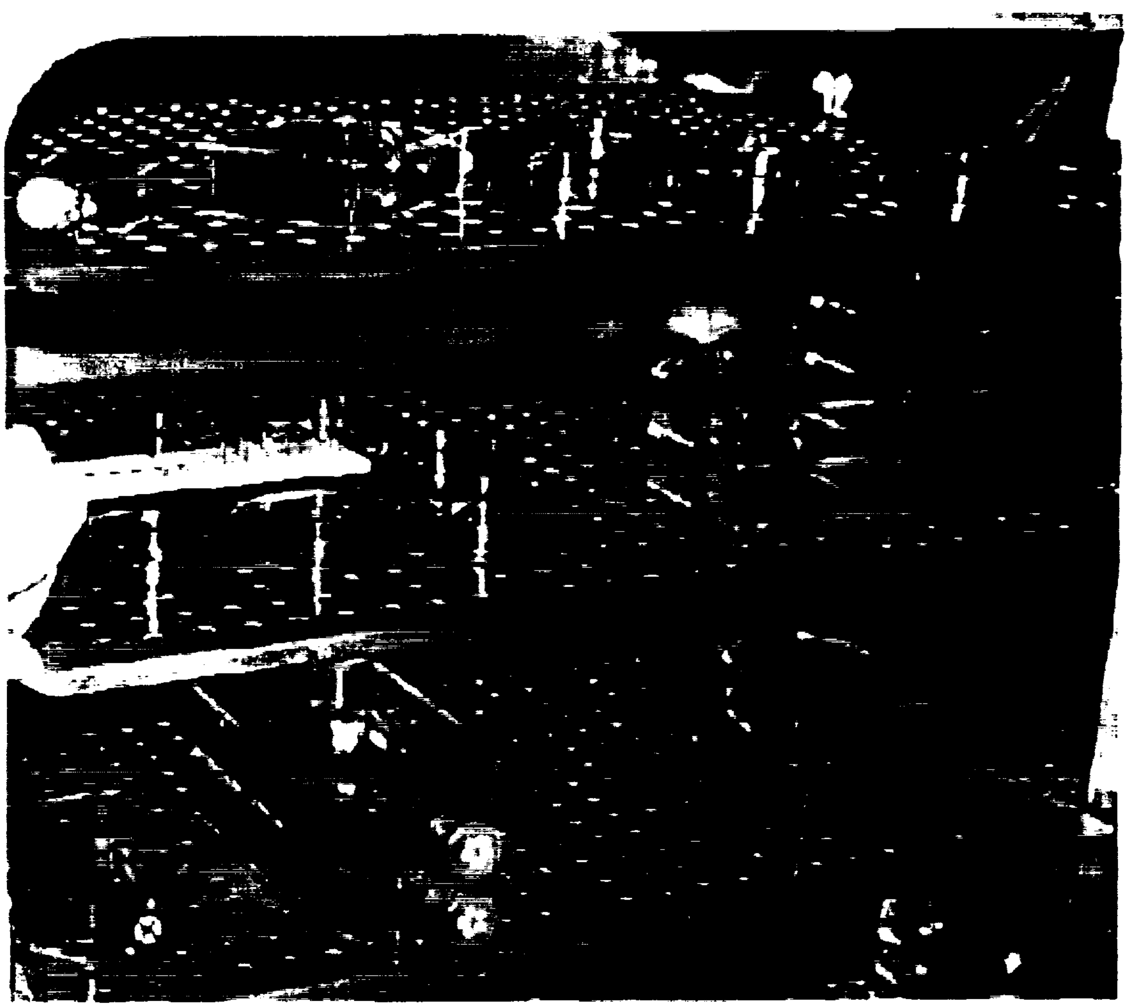

Technology Category: Biotechnology

BIO4 Electrically Potentiated Growth of Mammalian Neuronal Tissues Facilitated by Rotating-Wall Vessel Culture

Background

Development and differentiation of three-dimensional tissues in rotating-wall vessels (RWV), also known as the bioreactor, has been achieved for some mammalian and non-mammalian tissues. These tissues have developed functional capabilities, but as is the case with all normal tissues, grow extremely slowly. Therefore, development of an enhanced methodology "technology" to increase the rate of normal cell growth to that which approaches growth in the *in vivo* environment is of paramount importance.

Current research and testing with regard to development of methodologies to culture three-dimensional functional tissues, especially neuronal tissues, has been constrained by two factors: (1) the lack of a suitable environment to culture large-scale three dimensional tissues, *i.e.* the rotating-wall vessel, and (2) the inability to stimulate and enhance the growth rate of tissues, specifically neuronal tissues, with regard to an electrical rather than chemical stimulus.

Project Overview

This project will seek to couple the proven technology of the rotating-wall vessel and three-dimensional functional tissues with the addition of electrical potentiation across a solid substrate to provide enhanced growth rates and directionally-oriented tissues to accomplish construction of finite structures adaptable to neuronal transplantation. Preliminary work on electrical potentiation of tissue has been experimented with since the early 1980's; however, development of a successful model to demonstrate growth differentiation and the ability to transplant neuronal tissue has been unsuccessful, due to the inability to construct the model with the appropriate stimulus in a three-dimensional aspect.

Completion of such a model in a three-dimensional rotating-wall vessel environment will allow the development of directionally-oriented neuronal tissues, increased growth rates, and functional capabilities for transplantation in order to augment replacement, repair and stimulation of damaged neural tissues.

Additionally, development of this technology will lead to an advance in the already existing state-of-the art technology in RWV cellular construction and move the technology beyond the present boundaries for development of fragile tissues.

Benefits and Uses

Development of this technology will produce a complex three-dimensional *ex vivo* model (none exists) to study neural response to external stimuli and illuminate areas of neural development. Through these studies, the ability to culture and produce functional and potentially transplantable neural tissues should emerge. As a result, neural trauma due to accident (*i.e. spinal* cord damage) and disease, which in many cases is now irreparable, may be ameliorated via corrective techniques at the cellular level to replace or speed recovery of these damaged tissues.

Long-range applications of this technology may lead to an understanding of the methods by which neural tissues retain and convert electrical potential to chemical memory and how that memory is stored in three-dimensional neural tissue.

For further technical information, contact Thomas J. Goodwin at (281) 483-7129 or thomas.j.goodwin1@jsc.nasa.gov.
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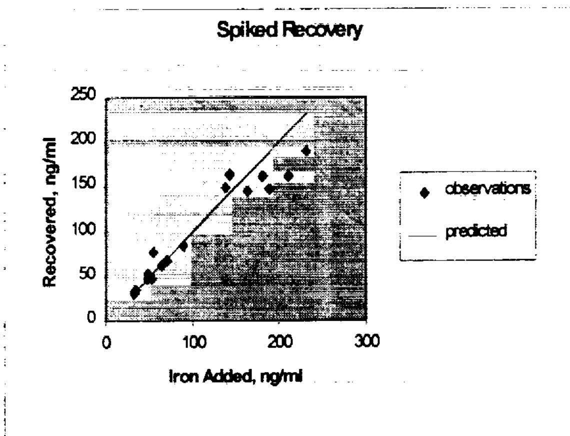
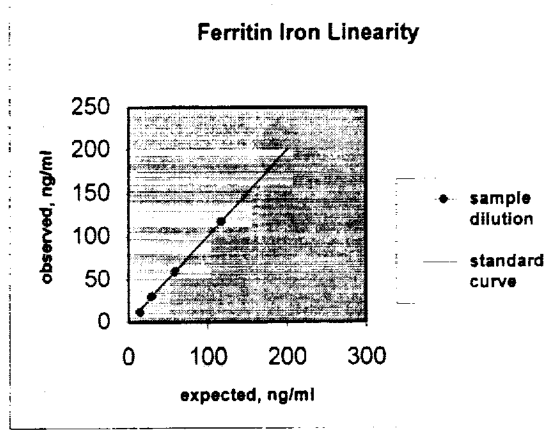
BIO5 Determination of Ferritin Iron by Inductively Coupled Plasma Mass Spectrometry





Technology Category: Biotechnology

BIO5 Determination of Ferritin Iron by Inductively Coupled Plasma Mass Spectrometry

Background

Serum ferritin determinations are currently used to assess iron stores in humans. Low levels of ferritin indicate the first stages of iron depletion. High serum ferritin levels may indicate a potentially fatal disease, hereditary hemochromatosis, which is characterized by progressive organ damage. Serum ferritin is also an acute phase reactant and may be elevated in response to an inflammatory process. In such cases, the elevated ferritin is actually apoferritin, which is the ferritin protein with very little iron in it and is therefore not a good measure of body iron stores.

Project Overview

Assessment of iron status and determination of dietary iron requirements are critical for maintaining crew health on extended duration space flights. Elevated iron stores, as suggested by elevated serum ferritin, have been observed during space flight. This increase continued well beyond the initial adaptation of blood volume to weightlessness. This elevation in iron stores may lead to oxidative damage, which is of great concern for exploration missions where the radiation exposure will be increased. In addition to the increase in serum ferritin, there is an increase in other serum proteins such as C3 complement and cortisol, which are both indicators of an inflammatory or stress response. Since inflammation is a confounding variable in the determination of iron status based on serum ferritin levels, measurement of the iron content in ferritin itself may be able to overcome this problem. This would make it possible to distinguish between increased ferritin levels due to iron overload and increased ferritin due to an inflammatory stress response.

Previous methods for measuring ferritin iron have been developed using large sample sizes, which are frequently unavailable with flight protocols. Therefore, a method had to be developed for isolation of iron using a very small sample size and a high level of sensitivity. This was accomplished by modifying sample preparation and using an inductively coupled plasma mass spectrometer (ICP-MS) with a sample injection micronebulizer for measurement of iron. ICP-MS is a relatively new analytical technique used to determine elements using mass spectrometry of ions generated by inductively coupled plasma. The development of our method for measuring ferritin iron is complete and validation studies including spiked recovery (see below), linearity (see below), and reproducibility have been performed with satisfactory results. Currently, we are performing studies on samples to determine the ability of the method to distinguish clinical changes in iron status. Future plans for measurement of ferritin iron before, during, and after space flight are in progress.

Benefits and Uses

A practical non-invasive laboratory method to assess iron status in populations has been a major clinical problem. Development of this technology could be of benefit for use in clinical testing. There is a vendor currently working towards development of a clinical test or kit to accurately measure ferritin iron. Results from the use of this technology will benefit NASA in that determination of iron requirements during space flight will significantly affect development of the food system.

For further technical information, contact Dr. Scott M. Smith at (281) 483-7204 or scott.m.smith1@jsc.nasa.gov.
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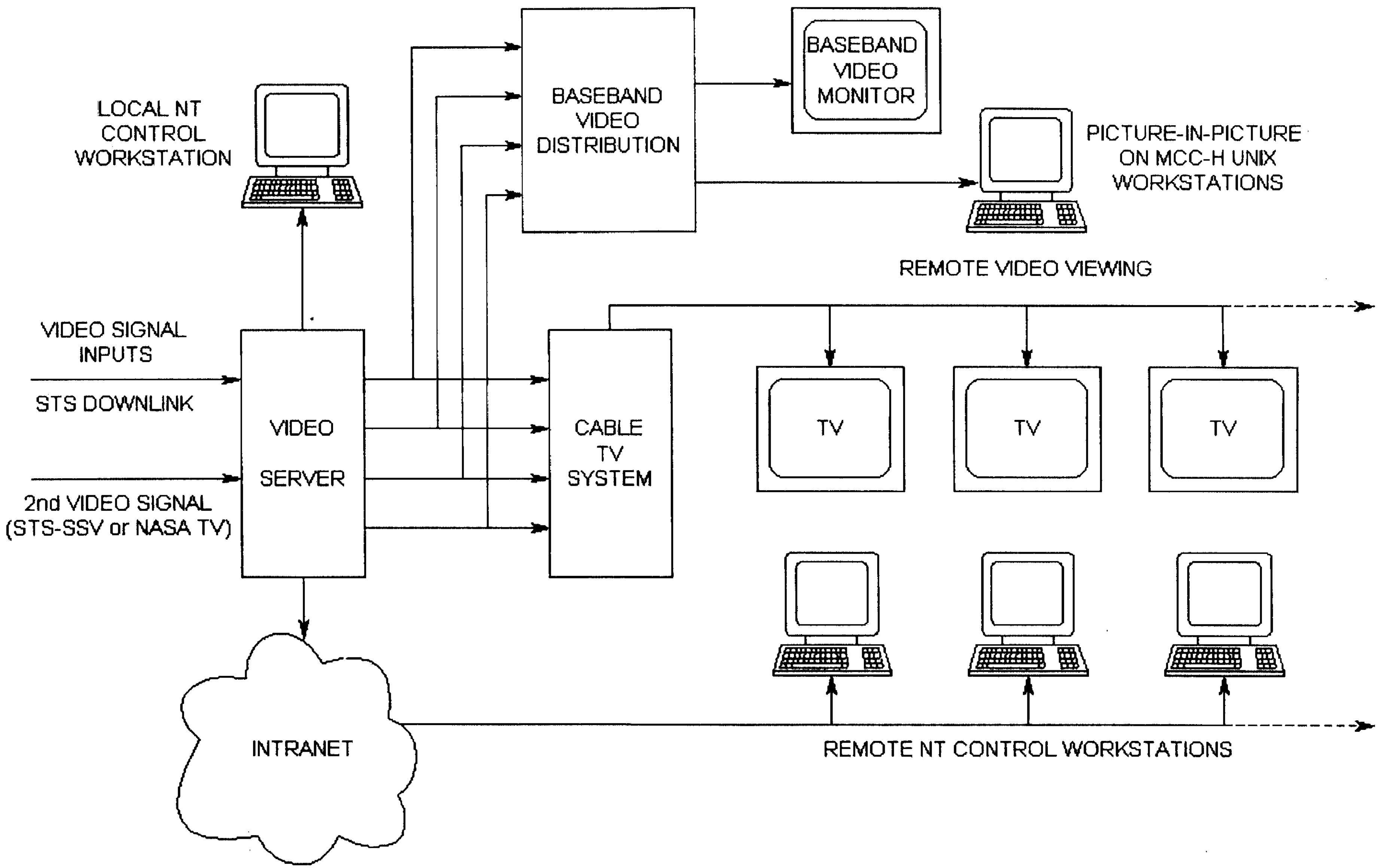
COMPUTER HARDWARE



OPERATION VIDEO SERVER SYSTEM

Technology Category: Computer Hardware

COM-1 Operational Video Server

Background

During Space Shuttle missions, a need frequently arises for a playback of segments of vehicle downlink or other video to the Mission Control Center (MCC) flight controllers, to engineering and payload teams or to mission managers. Currently, these requests are serviced by relaying a call through several operational consoles to a video system operator who locates the correct video recording, loads the video tape, cues the desired video segment, and then plays or replays the needed video over the existing Johnson Space Center video distribution systems.

Project Overview

The Operational Video Server project will provide a more responsive, more capable and less labor intensive solution to this video playback requirement using video server technology. With this system, the downlink video would be digitized in real time as it is received and stored on disk media. The system would initially be sized to store from 24-48 hours of the most recently received downlink video. Older video would still be available for viewing from traditional tape recordings or could be loaded onto the server for more immediate access. Other selected video segments, such as video of in-flight maintenance procedures, could also be stored on the video server system for ready access and display.

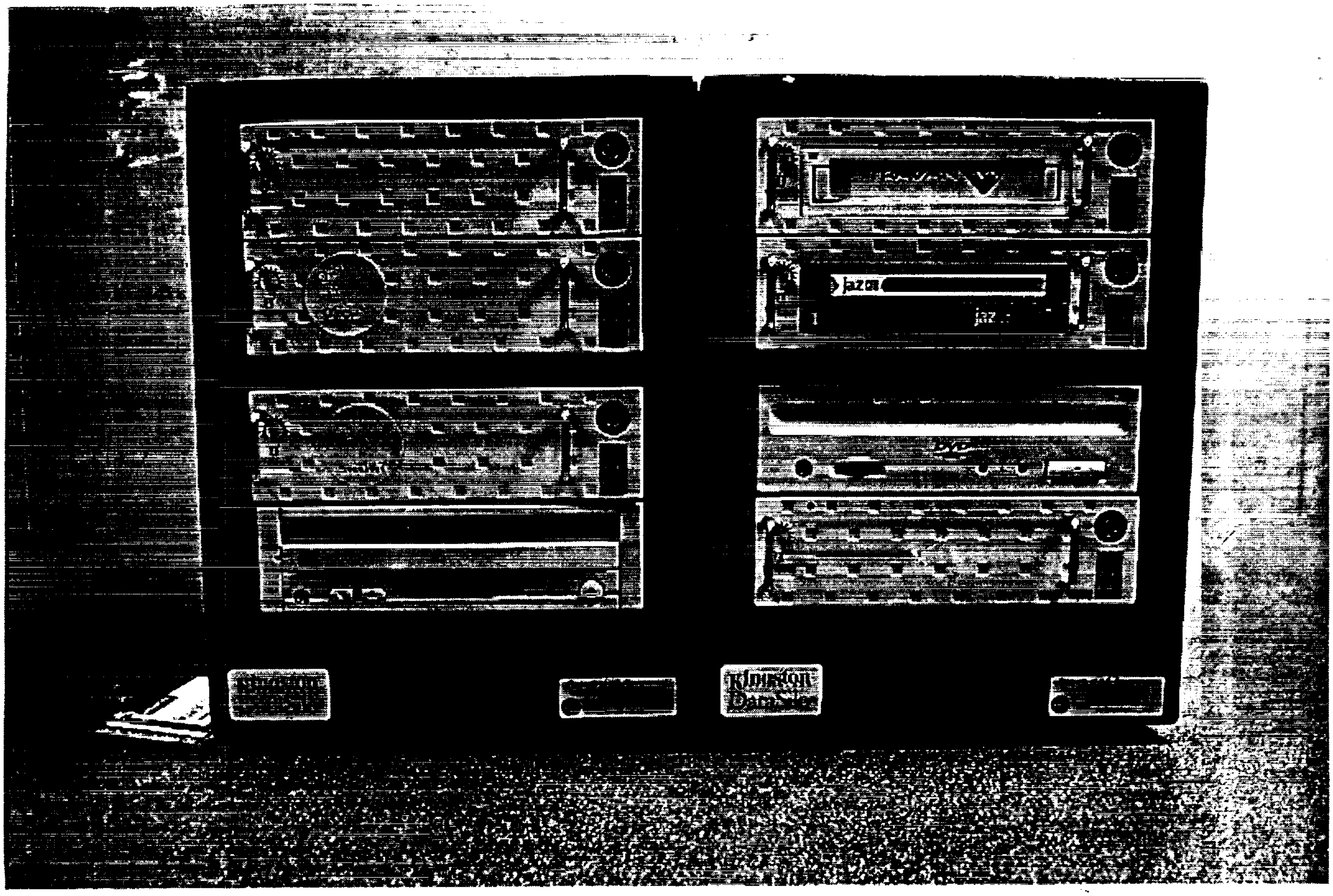
The video server will initially be configured to record up to two simultaneous video signal inputs and to play up to four different, simultaneous video signal outputs. Although the video will be digitized and compressed to approximately 8-24 Mbps, it will still be recorded at full resolution and full frame rate. The playback video will initially be distributed on site on a JSC Cable TV channel or via a baseband closed circuit video feed for viewing on a television monitor or as a picture-in-picture on an MCC operational UNIX workstation. One Windows NT based control workstation will be co-located with the server. A number of Windows NT based control workstations will be located within the MCC complex. These workstations will be running a unique video server control application and will communicate with the video server via the Center Intranet. A system user would identify the beginning time reference of the desired video segment, which would then be played out of the system on demand. The equipment needed to provide this initial system capability has been specified and is currently in the acquisition stage.

A proposed future system enhancement is the development of a browser based control application, which would allow broader system access and use. Under this concept, a user could access the system from anywhere at JSC by accessing a special password protected web server using any web browser. Another proposed enhancement would be the streaming distribution of the video over the Center Intranet.

Benefits and Uses

The inherent operational change and benefit which will result from implementing this system is that the control of this video search, retrieval and playback system will be directly in the hands of those persons that need to see and use the imagery. A resource benefit of this system will be the improved support capabilities, such as significantly faster access to video imagery and an ability to service multiple simultaneous video playback requests. This operational capability could also be expanded and used to support payload, science, management and public affairs users both at JSC and off site. Another benefit provided by the deployment of an operational video server will be the increased efficiency and future support labor cost avoidance associated with the implementation of this automated video system.

For further technical information, contact Daniel S. Willett at (281) 483-7010 or daniel.s.willett1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.



Technology Category: Computer Hardware

COM-2 Inflight Storage System for On-Board Training

Background

Current human spaceflight programs rely heavily on conducting all mission training preflight. For short duration missions, such as the Shuttle, this makes practical sense. However, for long and very long duration missions, it is neither practical nor possible to train for all nominal and contingency tasks that will be encountered.

As part of the NASA/Mir Phase 1 Program, extensive On-Board Training (OBT) was conducted and revealed the need for large capacity computer storage to support OBT delivery. This project was designed to leverage off COTS technologies and apply them in a fashion specific to NASA needs. From the onset, future upgradability was incorporated into the design so that as technology and user needs evolved, the system could easily accommodate these changes.

Project Overview

While the International Space Station (ISS) Program had envisioned the need for on board storage of electronic resources, due to the long lead time required for design and operations concept development, the storage needs grew at a much faster rate than the baseline design could accommodate. Additionally, the design had been baselined prior to the operation experience obtained as part of the NASA/Mir missions.

With the experience gained on Mir and with the desire to not unduly effect the baseline design, a rapid hardware prototyping effort was put in place. The basic design requirements only included large hard drives, but with an eye to the future, as well as an assessment of the existing ISS server capabilities, many other features were added to the system.

The current prototype consists of a SCSI PCMCIA interface card, power cables, two SCSI towers (each with 4 half-height bays), 2 permanently mounted devices (DVD drive and CD-R/W drive), a removable 2GB Jaz drive, a removable 20GB Travan Tape drive, and 4 removable 18.2GB hard drives. All of the removable devices are hot-swappable, a significant benefit given the operational nature of the device.

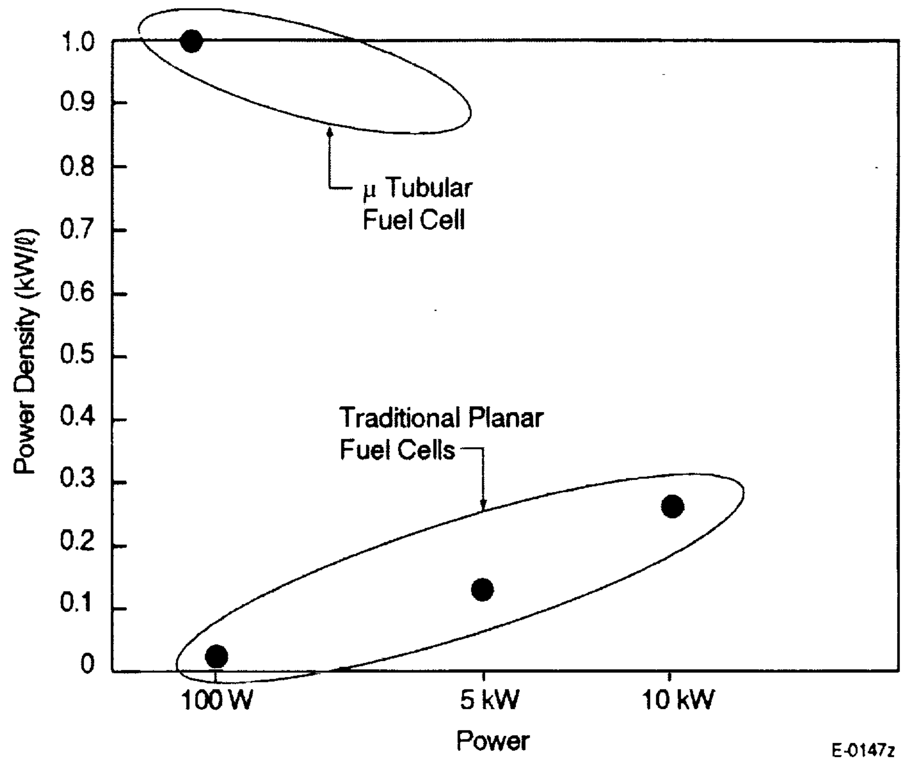
Benefits and Uses

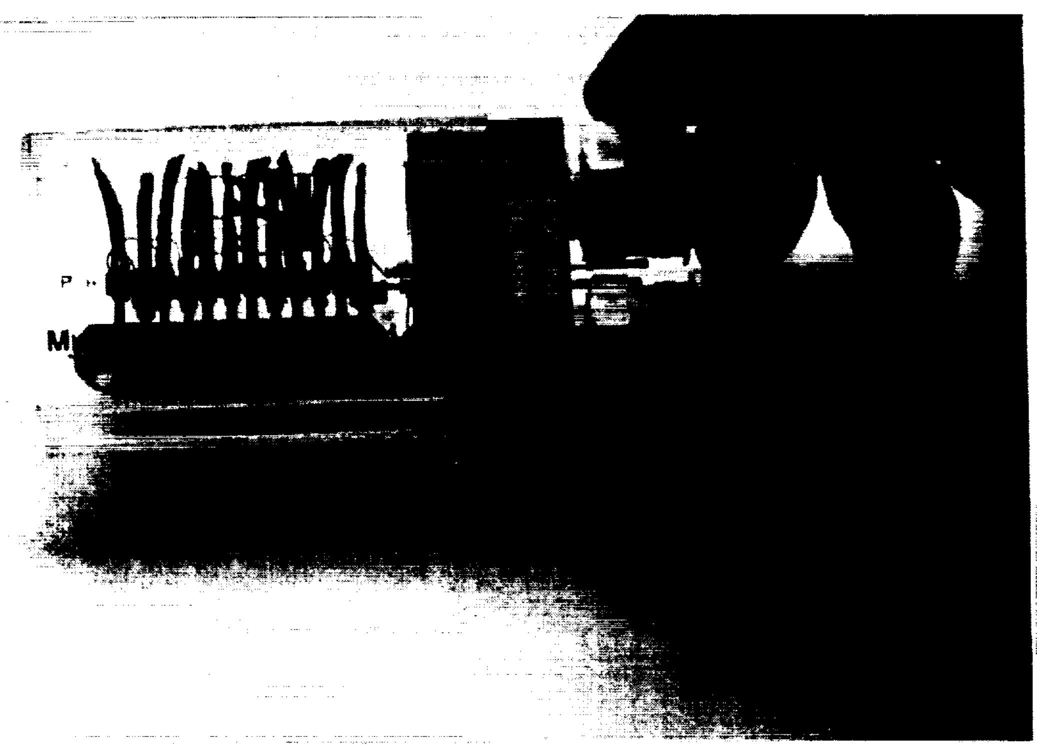
With the capabilities of this device, the ISS Program now has storage capacity in excess of 9 times the baseline design, with the ability to further augment the in-flight configuration. The ability to generate CD-ROMS in orbit is also a new significant capability, as magnetic media is less stable than CD due to the effects of radiation.

The device also will be a proving ground for non-Low Earth Orbit (LEO) mission. In order to leave LEO, significant computer resources must be readily available for the onboard crew. In this manner, the device is an enabling technology for Lunar and Mars missions.

For further technical assistance, contact Sean Kelly at (281) 244-7484 or sean.m.kelly1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

ENERGY





V-1841

A Revolutionary Approach to Maximizing PEM Fuel Cell Power Density

Technology Category - Energy

ENR-1 Micro-Tubular PEM Fuel Cells

Background

The development of proton exchange membrane (PEM) fuel cells has traditionally focused on producing large power stacks typically in a range of 1-250 kilowatts (kW's) for automotive to stationary power generation applications. For low power applications including laptop computers and portable power tools, fuel cell vendors are being challenged to develop a low cost, high power density fuel cell packaged in an extremely small volume. Currently most developers of these portable PEM fuel cell stacks simply utilize the traditional plate and frame design of the large stacks and shrunk the size of these stacks into small volume. This approach has resulted in a very low power density stack of less than 0.1 kw/kg and 0.1 kw/liter. In a Small Business Innovation Research (SBIR) Phase I program with NASA, Physical Sciences Inc. has demonstrated a feasibility of a micro-tubular fuel cell design that could have a power density greater than 1kw/liter when operating with oxygen and hydrogen gases at ambient pressure conditions.

Project Overview

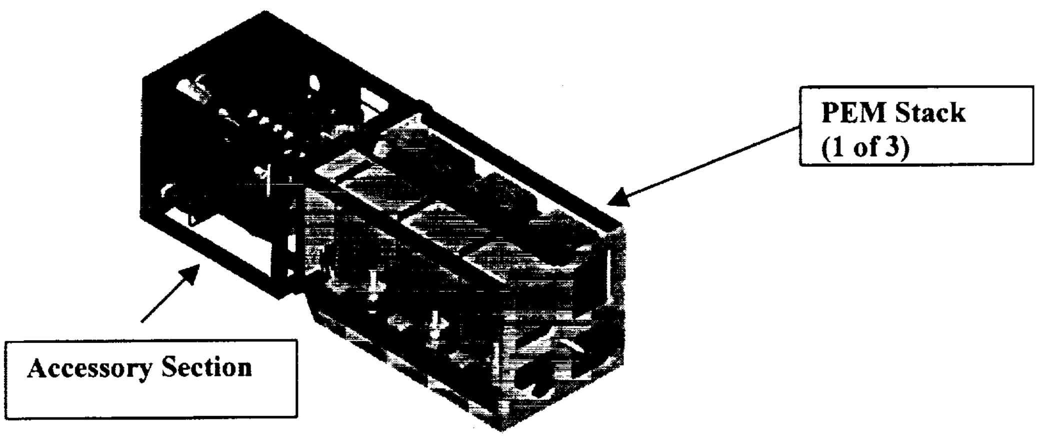
The purpose of this program is to demonstrate the capability of a different design approach to the traditional plate and frame design typically found in large power producing fuel cell stacks. The micro-tubular PEM fuel cell concept is based upon two driving principles: 1) the low currents generated in each tubular cell allow edge-tab current collection and transfer; and 2) the low polarization of the anode (hydrogen side) allows the anode area to be much smaller than the cathode area. The combined effects of the above principles enable a significant reduction in overhead mass and volume associated with the filter-press plate design, reduction in ohmic heating due to large current conduction between cells and increasing packaging density of cells. Design study of this concept indicated that a power density of 6 to 8 kW/liter is feasible. Single and 2-cell stacks have been built, tested, and compared with similar size of filter-press designed cells. Preliminary test results indicated an 88% improvement in power density with the micro-tubular cells. Based on this result, a 12 volt, 100 watt fuel cell stack is projected to be capable of achieving the 1 kW/liter goal. Additional improvement can also be realized with optimum selection of materials, packaging concept and operating conditions.

Benefits and Uses

Applications for the micro-tubular fuel cell include power generation for NASA spacesuits, surface power systems on Mars and Moon surface , transportation systems including rovers and miniature spacecrafts. Military applications range from portable power sources for the foot soldier to undersea vehicle power supplies. Commercial applications for compact low power sources are numerous. Portable electronics devices such as laptop computers, cell phones, tools, and games are immediate market niches.

For further technical information, contact Michael Le at 281-483-9039 and michael.le1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

ENR-2 Advanced Development of PEM Fuel Cells



PEM Fuel Cell

Technology Category - Energy

ENR-2 Advanced Development of PEM Fuel Cells

Background

The objective of this task is to develop proton exchange membrane (PEM) fuel cells to replace the existing alkaline fuel cells used on the Space Shuttle. Successful completion of this NASA-led multi-year technology program would significantly reduce the cost and technical risk of Shuttle PEM fuel cell development program. PEM technology is being pursued due to robustness of the cell stacks and the potential logistical cost savings to the Space Shuttle Program and future missions.

Project Overview

This technology program evaluates potential PEM fuel cell system designs and components through testing and analysis tasks to assure that the Shuttle requirements can be met by the PEM fuel cell. Vendor supplied fuel cells and combinations of vendor and JSC designed accessory section components are tested and analyzed to determine acceptability in the proposed application. Reactant gas recirculation devices and water-gas separators are being evaluated to characterize performance and identify areas of design improvement. Additionally, durability of the PEM stacks is being evaluated through long-term testing of vendor hardware.

Preliminary designs for systems have been completed and cell stack performance data through 10,000 hours operation on hydrogen and oxygen have been accumulated. Demonstration of a fuel cell product water management design concept is planned in 1999 with a determination of system feasibility in early 2000. An evolution into a higher fidelity system for evaluation purposes is planned in 2000 and 2001.

Benefits and Uses

PEM fuel cells are expected to have a longer life, higher power capability and a lower operating cost than the current alkaline fuel cell system. PEM fuel cells are being developed for other commercial applications, including electric cars and portable power sources. Some of the work these commercial applications are performing to advance the technology is applicable to PEM fuel cells for space.

This technology has been submitted as a new invention disclosure.

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For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

National A[illegible] [illegible]
Space Administ[illegible]

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Lyndon B. Johnson Space Center
Houston, Texas 7705[illegible]

Technology Category: Energy

ENR-3 Solar Heat Pump Development

Background

Thermal control systems require significant mass, volume, and energy resources. Air-conditioners and refrigerators are thermal control systems on Earth that use a heat pump cycle. These types of systems are required in space as well. For both aerospace and many Earth applications, solar energy is a good power source because it is most available at midday when the heat pump is required the most. Johnson Space Center and several industry partners have been cooperating for several years to develop highly efficient solar heat pumps to solve various problems.

Project Overview

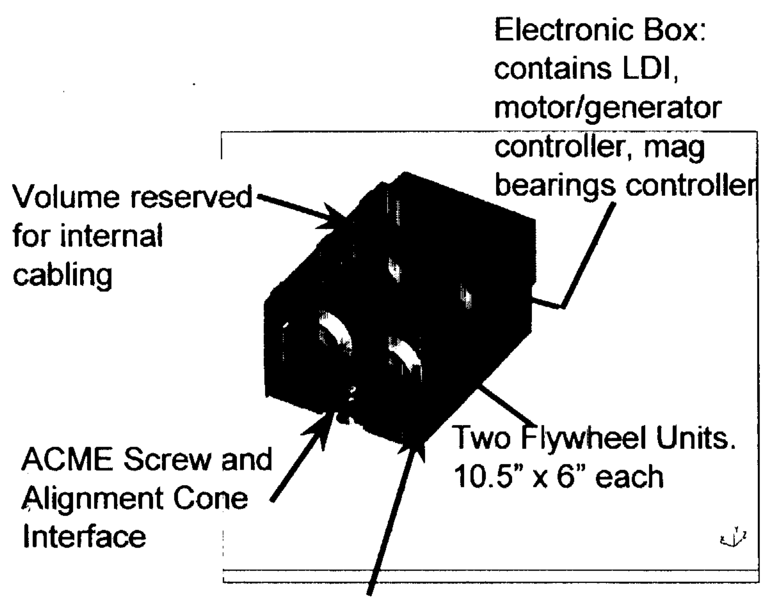
A NASA site was one of five test sites in the United States chosen as part of the Electric Power Research Institute Solar Photovoltaic Heat Pump Project. In this project, a photovoltaic (PV) vapor compression cycle heat pump was operated at the Johnson Space Center Advanced Life Support Laboratory from 1994 to 1997 to demonstrate the integration of solar PV panels and cooling systems. The Crew and Thermal Systems Division also completed the conceptual design of a lunar base solar PV heat pump using a similar arrangement to reduce power system mass by 43% through direct coupling to the heat pump.

Three smaller-scale solar heat pumps were also tested from 1996 to 1999 in a solar PV refrigerator application. Thermoelectric, Stirling, and vapor compression heat pumps were tested (one at a time) in the same vacuum-insulated refrigerator cabinet. They relied on thermal energy storage to stay cold during the night and cloudy days rather than using batteries to store electrical energy. Besides the space application for the advanced refrigerators, there is a vast commercial potential for solar refrigeration on Earth.

Benefits and Uses

Solar energy technology, long recognized as environmentally benign, has practical applications in both aerospace and Earth-based energy systems. Solar heat pumps can significantly reduce the mass of thermal control systems on spacecraft for future human missions such as a lunar or Mars base habitat. On Earth, solar heat pumps are a promising technology for a variety of cooling applications such as refrigerators and freezers. Due to JSC's recent developments, this technology may soon be available for licensing.

For further technical information, contact Mike Ewert at (281) 483-9134 or michael.k.ewert1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.



ACESE's Component Summary

Attitude Control & Energy Storage Experiment - ACESE

Technology Category: Energy

ENR-4 Flywheel Energy Storage

Background

The current International Space Station (ISS) batteries must be periodically replaced, approximately every 4 years. These batteries are heavy and require a significant commitment of Shuttle upmass/upvolume resources. The batteries are required to store energy during the sunlit periods of the orbit for ISS use during the dark side of the orbit. The high (50k to 100k) revolutions per minute (RPM) flywheels, using advanced materials and system components, may never need to be replaced and are more efficient at storing and discharging energy.

Project Overview

The flywheel stores electrical energy by spinning up the two contra-rotating flywheels suspended on magnetic bearings when an excess of electrical power is available during the sunlit portion of the orbit. The two flywheels are contra-rotating to balance out disturbance torques to ISS. The stored energy is then discharged and used to supply power for general ISS use during the dark side of the orbit. The flywheels will operate at approximately 60,000 RPM and store 2.4kW-hr of energy.

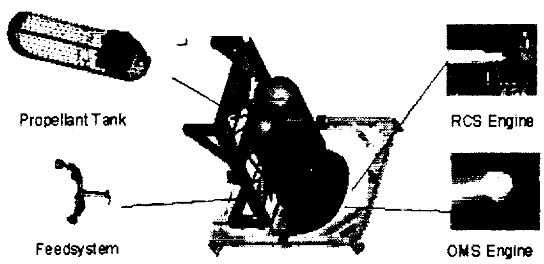
The flywheel was selected as an Engineering Research and Technology payload initially, and will be demonstrated on an upcoming Shuttle flight. It will likely be installed in a location that would have otherwise have been used for a set of batteries. If the demonstration is successful, the flywheel will remain in place and continue to be used for energy storage. Based on the results of the demonstration, the ISS program will decide on the purchase of additional flywheel units to be used to replace the currently installed ISS batteries (when maintenance would normally require replacement) and for use instead of additional batteries which are scheduled to be installed later in the ISS assembly sequence.

Benefits and Uses

The use of the flywheel will decrease Shuttle upmass/upvolume requirements for ISS maintenance, increase the ISS energy storage/discharge efficiency (versus the batteries), and provides the added benefit of providing rotational momentum which can be used for ISS attitude control (by creating a difference in the spin rates between the two contra rotating wheels). The sponsors and developers of the flywheel have also been supporting other industry interest in developing smaller flywheels for a wide range of applications in industry. The NASA Glenn Research Center, the U.S. Air Force and their contractors are extensively involved in this activity.

For further technical information, contact Al Holt at (281) 244-8394 or al.holt1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

ENR-5 Non-Toxic Orbital Maneuvering & Reaction Control System



ENR-5 Non-Toxic Orbital Maneuvering & Reaction Control System

Background

The current use of toxic propellant on the Space Shuttle creates flight and ground safety hazards and long turnaround times. Previous attempts to develop non-toxic propellants for reaction control system have focused on pump-fed systems using hydrogen propellants. This has not been entirely successful or practical for large reusable vehicles, such as the shuttle. The technology for a Non-Toxic Orbital Maneuvering and Reaction Control System (NT OMS/RCS) simplifies the system by utilizing a pressure-fed liquid oxygen and ethanol system. The result is a system that is safer, more reliable, and simpler to operate.

Project Overview

The purpose of this research and technology is to demonstrate that the NT OMS/RCS system can be flown and operated for a reusable launch vehicle such as the shuttle. The NT OMS/RCS provides critical on-orbit maneuvers, de-orbit burns, docking maneuvers, and space station re-boost functions. The design uses pressure-fed liquid oxygen and ethanol stored at 250-350 psia. This high pressure increases the sub-cooling of the liquid oxygen, thereby resulting in improved storability of the cryogenic oxygen. A variety of cryogenic insulation technologies are being evaluated to reduce heat leak into the tanks. The project has completed tank designs and component demonstration of the RCS and OMS engines. Tests on a dual thrust RCS engine and a cryogenic RCS feed system will be completed in 1999. In the next phase starting in 2000 and completed 2002, a full system will be assembled and tested in a space environment.

Benefits and Uses

The primary benefit of NT OMS/RCS is improved safety. The non-toxic propellants are not carcinogenic and are less of a fire hazard. The processing time savings that results from using non-toxic propellants over toxic propellants is 65%. For the Space Shuttle, this saves over $24 million per year and reduces processing time from 43 days to 8 days.

The NT OMS/RCS also improves performance more than 5% over current toxic propellant. For the shuttle, this means a payload increase of up to 3400 lbm, which is significant. The dual thrust RCS engine technology that is part of the NT OMS/RCS improves vehicle control and re-boost capability.

There are a wide variety of uses for NT OMS/RCS technology on commercial reusable launch vehicles. The cryogenic liquid oxygen technologies also have application in other fields such as life support and power generation.

This technology has been disclosed as a new invention.

For further technical information, contact Eric Hurlbert at (281) 483-9016 or eric.a.hurlbert1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

National Aeronautics and Space Administration

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Houston Texas 77058

Technology Category: Energy

ENR-6 Mars In-situ Propellant Production Precursor Flight Demonstration Project

Background

Strategic planning for human exploration missions to Mars has identified in-situ propellant production (ISPP) as a highly desirable technology. A team of engineers from the Johnson Space Center, Jet Propulsion Laboratory, and Glenn Research Center is preparing the Mars ISPP Precursor (MIP) Flight Demonstration. The objective of MIP is to characterize the performance of processes and hardware which are important to ISPP concepts and which interact directly with the Mars environment. Because of uncertainties associated with the Mars environment and conditions that cannot be adequately simulated on Earth, operating this hardware in the actual Mars environment is extremely important.

Project Overview

Manifested for launch to Mars onboard the Surveyor Lander in April 2001, the MIP Flight Demonstration will be the first hardware to utilize the indigenous resources of a planet or moon. Its successful operation will pave the way for future robotic and human missions to manufacture and rely on propellants produced using Martian resources as feedstock.

The MIP is comprised of five distinctive experiments; their purpose is to:

- Selectively absorb and compress carbon dioxide from the Martian atmosphere;
- Produce propellant-grade, pure oxygen;
- Test advanced photovoltaic solar cells for energy production;
- Test techniques to mitigate the settling of airborne dust onto solar arrays; and
- Test thermal radiators;

The MIP package will be designed to be small and lightweight. Design requirements are for an overall maximum external envelope of approximately 40 x 24 x 25 cm (15.7 x 9.4 x 9.8 inches) and a package mass of 8.5 kg (18.7 lbm).

Benefits and Uses

The successful performance of the five individual demonstrations of MIP will provide both knowledge of and confidence in the reliability of this technology. At the completion of this flight demonstration, the MIP Team will be able to:

- Recommend preferred hardware configurations for the intake and adsorption of carbon dioxide from the Martian atmosphere;
- Recommend preferred hardware designs for innovative thermal management including the radiation of heat to the outside environment;
- Understand long-term performance degradation characteristics of advanced solar array and radiator concepts operated in the actual Mars environment;
- Evaluate the functionality of electrostatically repelling airborne dust from landing on the solar array; and
- Understand the performance characteristics of zirconia cells to generate propellant-grade oxygen.

For further technical information, contact David Kaplan at (281) (281) 483-7667 or david.kaplan@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

ENVIRONMENTAL

ENV-1 Bio-Plex

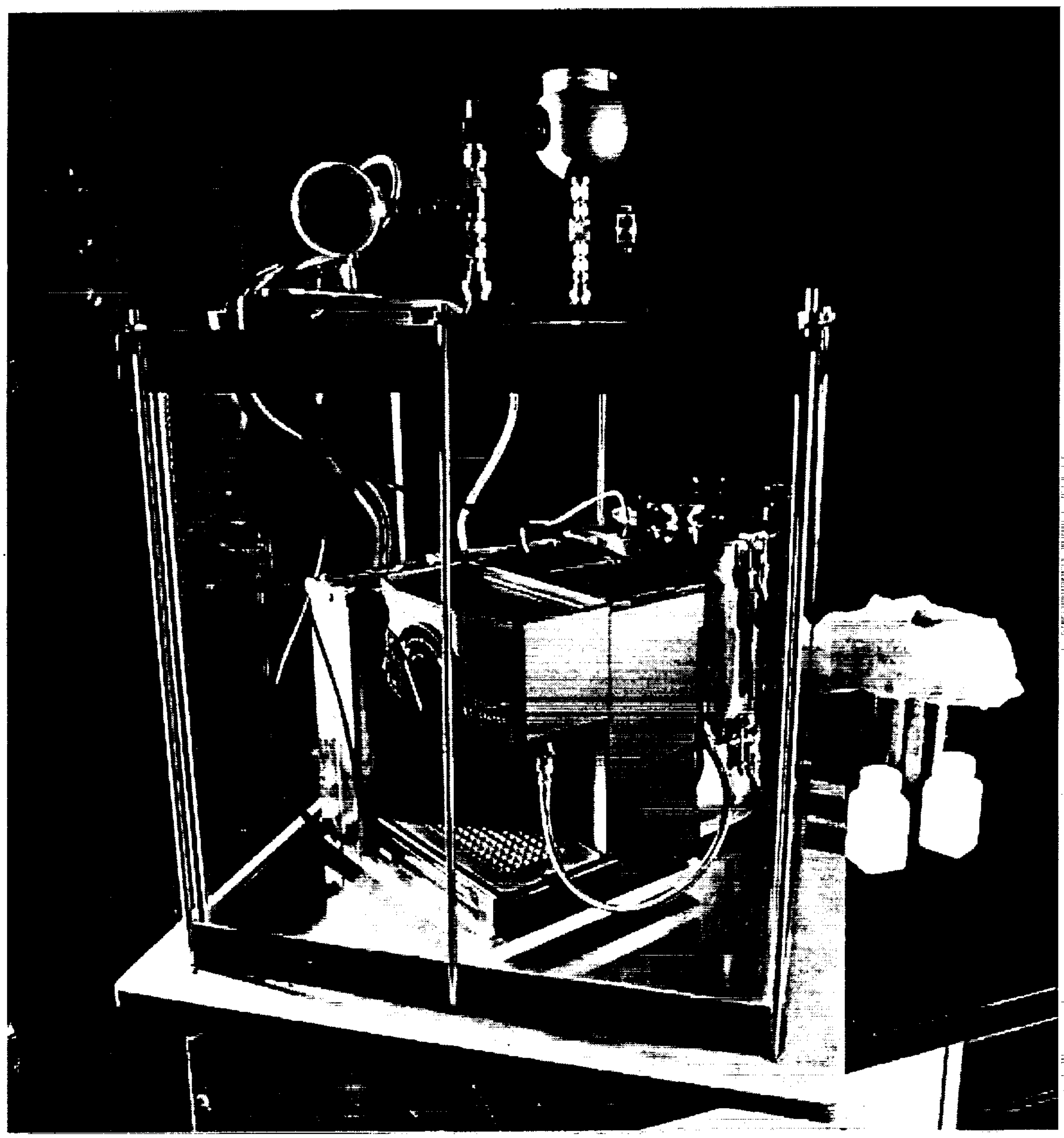

Figure 1. Volatile analysis setup for a soy milk machine.

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Technology Category: Environmental

ENV-1 Bio-Plex

Background

NASA-JSC is constructing a ground-based testbed (BIO-Plex, Bioregenerative Planetary Life Support Systems Test Complex) to simulate confined environments required for long duration missions, such as a Lunar outpost or an extended mission to Mars. This testbed will use crops to perform life support functions under the restrictions of optimizing volume, mass, energy, and labor and with the goal of near complete closure of processes for regeneration of air, water, and food. The food system will be based on raw food products obtained from higher plants grown in controlled environmental chambers and processed in the interconnecting tunnel. Food processing in this closed system will have a significant impact on water requirements, waste production and air revitalization, which may affect crew health and safety. Specifically, the goal for this project was to assess the impact of food processing on air quality by identifying and quantifying the volatiles evolved from different food processing equipment.

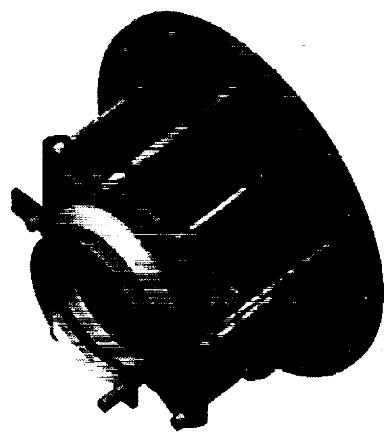
Project Overview

Wheat and soybeans are baselined to be grown in the BIO-Plex. Therefore, various food processing equipment are required to convert these crops into edible products such as bread, soy milk and pasta. Volatiles evolved from a bread machine, a soy milk machine and an extruder were analyzed. The bread machine and soy milk machine were placed individually inside an air-tight chamber (volume $\approx$ 0.12 m^3) and an air sample was drawn using an evacuated sample bomb (500 mL). For the extruder, the air sample was drawn from specially designed bags which were attached to the extruder barrel. All samples were analyzed using a gas chromatograph-mass spectrometer. Results show the production of alcohols, aldehydes, ketones and various other compounds from food processing. In particular, ethanol and acetaldehyde were shown to exceed the 180 day Space Craft Maximum Allowable Concentrations for the BIO-Plex if no means of scrubbing for the volatiles is used. Additionally, some equipment may need to be placed under a fume hood when used, to avoid excessive production of these volatiles.

Benefits and Uses

Similar data may be required when people are exposed to volatiles evolved during the operation of various types of equipment in enclosed areas for extended periods of time. These enclosed environments include submarines and remote bases in the Antarctic. It is important to realize that food processing equipment may contribute to an accumulation of volatile compounds which may accumulate to a concentration which may be hazardous to human health.

For further technical information, contact Dr. Charles Bourland at (281) 483-3632, charles.t.bourland1@jsc.nasa.gov, or Dr. Yael Vodovotz at (281) 483-7632, vael.vodovotz1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.



Metal Monolith Catalytic Converter (MMCC)

Technology Category: Energy

ENV-2 Metal Monolith Catalytic Converter

Background

The internal atmosphere on the International Space Station (ISS) must be continuously filtered to remove carbon dioxide (and carbon monoxide). The units which are currently used to accomplish this require fairly frequent maintenance and replacement, representing significant crew time and transport to orbit requirements.

Project Overview

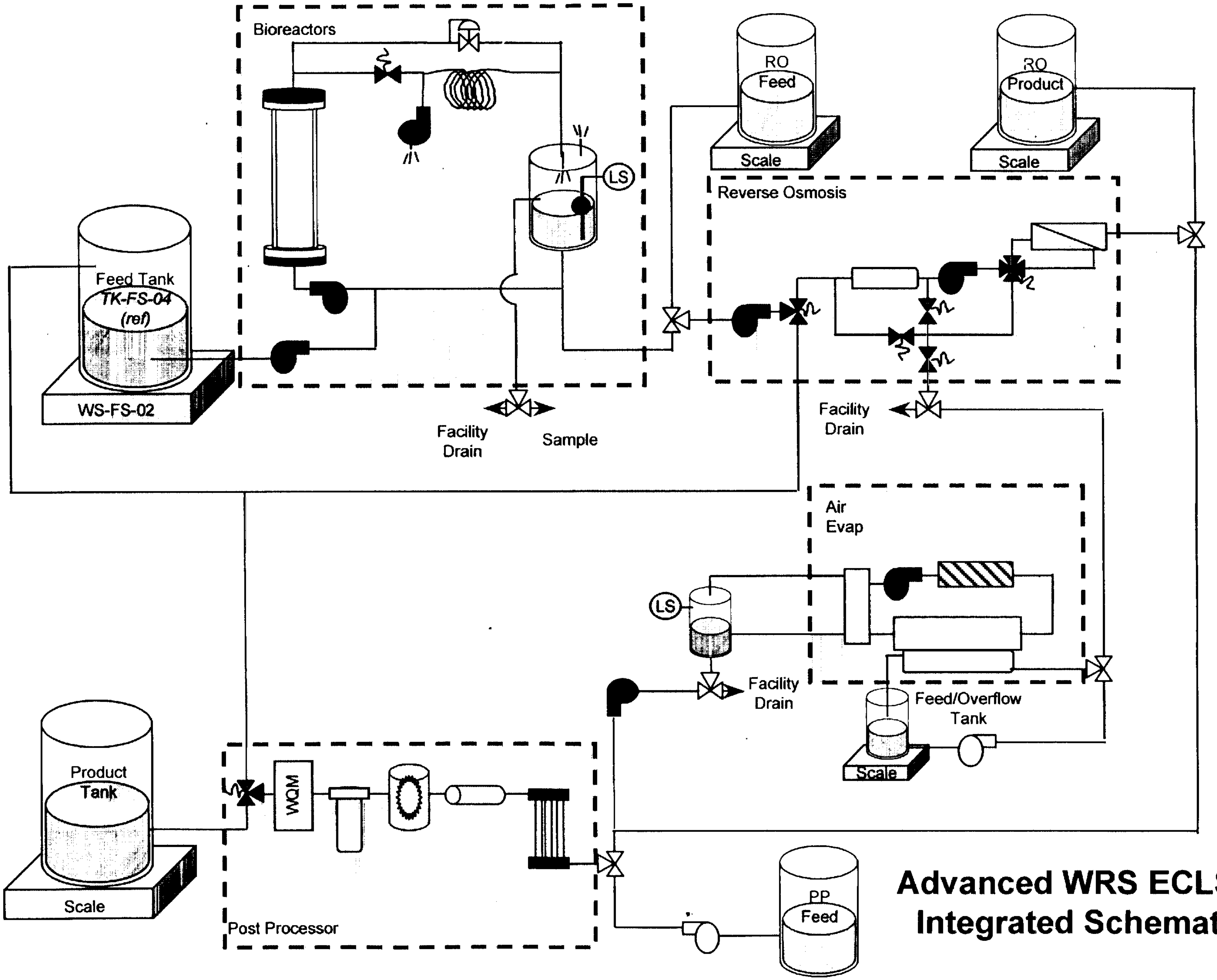
The Metal Monolith Catalytic Converter is based upon innovative reactor design techniques using high cell density, short channel length metal monoliths and specialized catalytic coating processes to extend catalytic oxidizer service life by at least 5 years and charcoal bed service life by 2-3 years.

This development and ground testing was originally selected as an Engineering Research and Technology experiment. The testing work has been completed and the technology will be demonstrated by installing it on the ISS at an appropriate maintenance opportunity.

Benefits and Uses

In addition to providing the longer life and greater time between maintenance requirements, the converter also will provide a 41% reduction in power and will provide a 98% reduction in the amount of time required for the system to recover from a system poisoning event as compared to the current system. The converter was originally developed through a Small Business Innovation Research activity. The Phase A design effort for a flight unit and associated integrated tests of a flight type unit with a ground version of the ISS Environmental Control and Life Support System have been completed.

For further technical information, contact Al Holt at (281) 244-8394 or al.holt1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.



Advanced WRS ECLSS Integrated Schematic

Technology Category: Environmental

ENV-3 Biological Water Processing Systems Development

Background

The purpose of the biological water processing systems development project is to create an advanced water recovery system based on microbial bioreactors which convert the contaminants in the water into basic chemical forms. The system handles a combined feed stream, which prevents the need to separate urine from the remainder of the waste water that is generated which simplifies the system. By reacting the contaminants instead of adsorbing or exchanging them, consumables are greatly reduced and mass for long duration missions becomes more realistic. Additionally, the system that is being developed recovers essentially 100% of the waste water so that no brine waste solution is generated. This prevents the need for resupply water, which also saves on mass for long duration missions. The research is currently focused on addressing the adaptation of the proven ground technology to a microgravity environment.

Project Overview

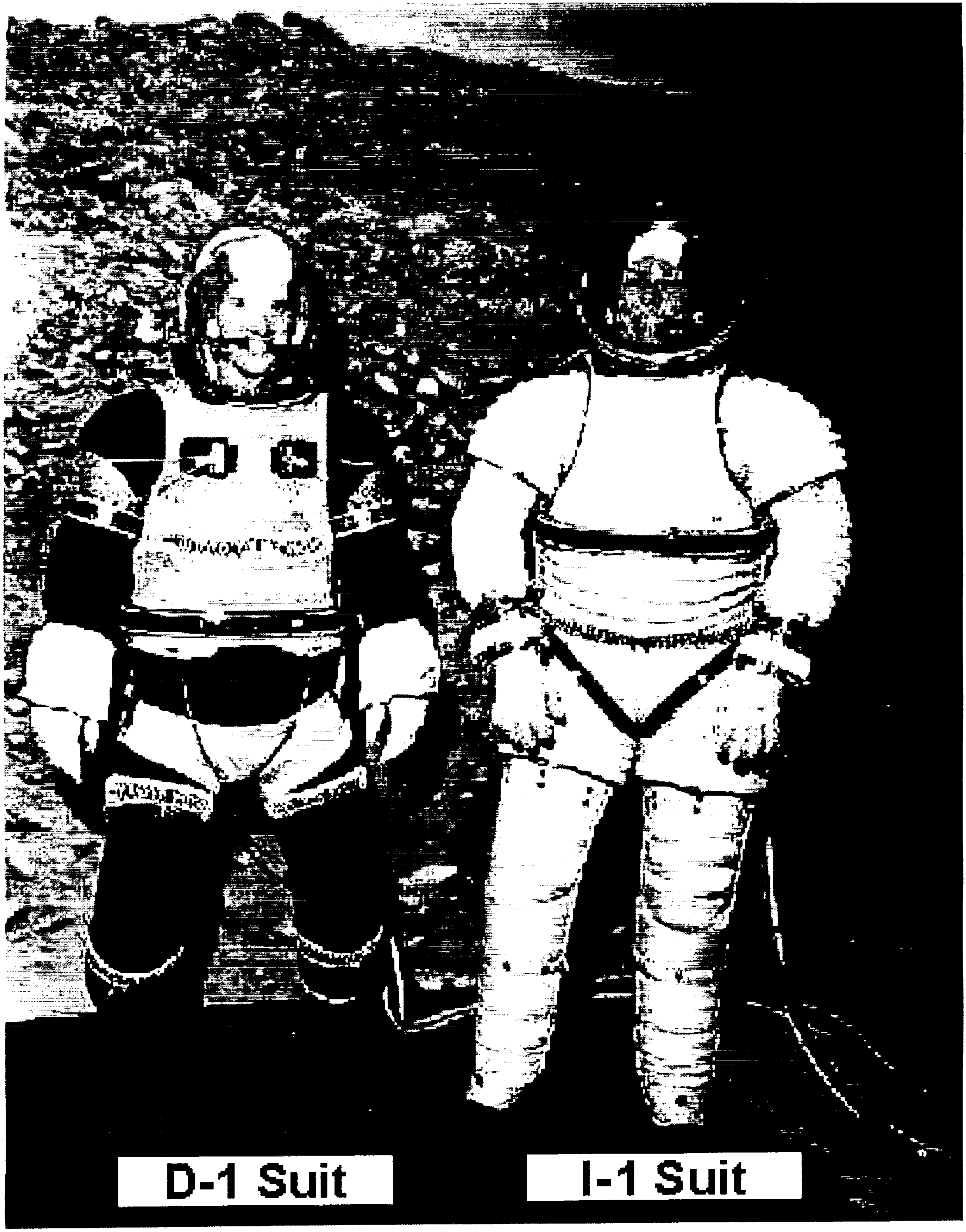
The purpose of the technology is to develop a water recovery system that purifies 100% of the incoming waste water while using less expendables than the current state of the art systems while working in a microgravity environment. The system is composed of 5 subsystems: an anaerobic packed bed bioreactor for degrading organic carbon; an aerobic tubular bioreactor for converting ammonia to nitrate; a reverse osmosis system for separation of salts from the waste stream; an air evaporation system for recovery of the water in the reverse osmosis brine; and a post-processing system for residual organic carbon degradation and salt removal.

This technology has been successfully demonstrated at JSC with humans in a closed test chamber for 91 days. The technology is currently being developed as individual subsystems which will be integrated in early 2000 to test a completed system from waste water generation to potable water production.

Benefits and Uses

The benefits of this technology are the minimization of expendables by only using adsorbents and ion exchange resins when no other method is available for polishing instead of as the main processing step. The system being developed uses minimal power, is small and compact and generates very clean water. Alternative uses that are being investigated include remote locations where water is difficult to obtain. Work is being conducted with the Pike's Peak manager to develop a modified system for recycling gray water in the summit house. The technology is being actively pursued for application in specific areas.

For further technical information, contact Marybeth Edeen at (281) 483-9122 or marybeth.a.edeen1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.


D-1 Suit
I-1 Suit

Technology Category: Environmental

ENV-4 EVA Soft Space Suit Design

Background

Previous space suit assemblies incorporated a wide variety of both fabric elements, hardware structures and a combination of each to provide operational mobility capabilities while in a pressurized condition. These efforts, although achieving good mobility results, resulted in suit systems that were deemed to be too heavy and bulky. The recent development efforts undertaken by this research activity were initiated to investigate maximizing the use of fabric softgoods elements for both structural and mobility systems in order to minimize the weight and bulk of space suit assemblies while maintaining a high degree of pressurized mobility.

Project Overview

Two different lightweight configuration baseline advanced space suit assemblies have recently been developed to serve as mobility joint technology test beds for conducting and assessing various test subject pressurized comparative performance task activities. The D-1 (S1035X) space suit assembly, one of the two independent configurations, was designed and developed based on the current lightweight S1035 Advanced Crew Escape Suit (ACES) worn by Shuttle crewmembers during launch and re-entry phases of flight but upgraded to incorporate specific mobility enhancements. The design objective of the D-1 suit was for a predominantly "all-soft" (i.e., fabric) suit system which incorporated only upper arm bearings and could operate at a 3.75psi (25.8 kPa) pressure level. The D-1 suit weight was only 26 lbs. (11.8 kg). The second suit configuration, the I-1 space suit assembly, also designed for 3.75 psi (25.8 kPa) operational pressure, is a configuration that incorporates a limited number of bearing elements in the overall mobility system. Bearings are utilized only in the shoulders, upper arm and hip areas of the I-1 suit. The basic torso areas of both the D-1 and I-1 suits are composed of fabric structures as well as are the mobility joint elements located in the shoulder, elbow, waist, hip, knee, and ankle joint areas.

Benefits and Uses

A lightweight, all-fabric space suit system that exhibits a high degree of pressurized mobility would provide enhanced performance capabilities for future planetary surface explorers. The mobility features and materials selected for use in the advanced technology suit demonstrator models may have application in other diverse hazardous abatement equipment development areas.

For further technical information, contact Joseph Kosmo at (281) 483-9235 or joseph.j.kosmo1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

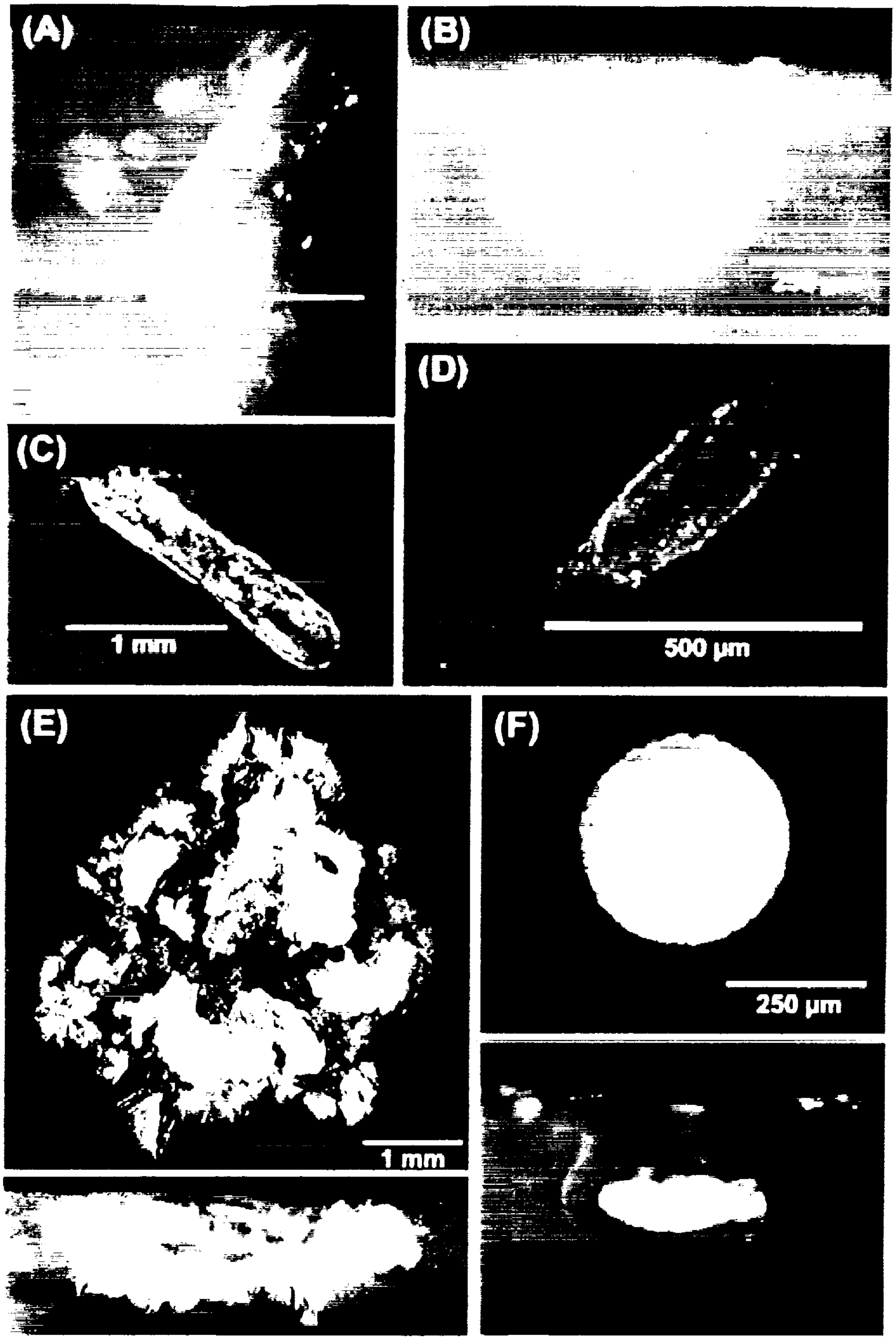


Figure 1. Representative impact features in aerogel exposed on Mir. a) Typical, deep, carrot-shaped penetration track; b) shallow, nearly hemispherical pit; c) cylindrical cavity intermediate between tracks and pits; d) cylindrical cavity displaying a parasitic track, the result of a small chance fragment; e) plan view (top panel) and cross section (bottom) of large, irregular depression caused by solid human waste; f) plan and side view of circular solution features caused by the encounter of waste-water droplets; note the thin deposit of evaporites lining the bottom of these features.

JSC Research & Technology Report 1998-1999

Technology Category: Environmental

ENV-5 Impact Features and Projectile Residues in Aerogel Exposed on Mir

Background

The low bulk densities (< 0.01g/cm3) and associated micro-structural properties of Si02-based aerogels, informally referred to as "frozen smoke", seem highly suited to gently decelerate hypervelocity particles. Laboratory tests at impact speeds as high as 7 km/s reveal that unmelted projectiles reside at the tip of deep, carrot-shaped penetration tracks and that these particles can be recovered for compositional and textural analyses using Scanning or Transmission Electron Microscopes. This renders aerogel the choice material to capture relatively unmodified projectiles in low Earth orbit (LEO) and to retrieve them to Earth for detailed mineralogical, compositional and textural characterizations.

Project Overview

The Mir Environmental Effects Package was deployed on Mir by STS 86 (March 1996) and retrieved after 18 months by STS 96. The Orbital Debris Collection Experiments (ODC) was part of this package and exposed 0.6 m2 of aerogel. Visual inspection of the space exposed aerogel reveals two classes of hypervelocity impact features: (1) long, carrot-shaped tracks (Fig. a) identical to those produced in the laboratory, and (2) shallow pits of nearly hemispherical shape (Fig. b) that have no laboratory analog. Blunt-nosed, cylindrically shaped cavities attest to transitional morphologies between tracks and pits (Fig. c and d). All deep tracks contain unmelted projectile residues. In contrast, the shallow pits rarely contain even traces of projectile material. These and other observations suggest that deep tracks form at systematically lower velocities than the shallow pits; projectiles of modest encounter speeds remain unmolten and penetrate deeply, yet high velocity impactors melt and vaporize close to the surface, making them poor penetrators. The threshold velocity for the successful capture of unmelted residues in aerogel of 0.02 g/cm3 is estimated to be at 15 to 18 km/s. Harvesting and analysis of individual projectiles, typically < 20 um in size, is in progress, yet we have identified already a variety of man-made materials (metallic aluminum, aluminum oxide, stainless steel, paints, and diverse electronic components) as well as natural cosmic dust, largely composed of the minerals olivine, pyroxene, spinel and troilite.

The ODC aerogel also contains numerous shallow depressions of irregular outlines that are occupied by tan to brown flakes (see Fig. e), some barely embedded into the aerogel, all representing very low impact speeds judging by the small volume of crushed aerogel (see Fig.e). Compositional analysis of these flakes reveals predominantly Na, K, S, P and Cl, and identifies them as human waste. We also observe numerous, exceptionally circular and bulbous structures, all <1 mm in diameter, each containing a thin film of tan to brown material in its Petri-dish shaped bottoms (Fig. f). This material is identical compositionally to the above flakes, illustrating that tiny droplets of waste water encountered the aerogel.

Benefits and Uses:

Our observations verify aerogel to be the capture medium of choice for hypervelocity particles in LEO, vastly superior to dense, non-porous targets. Some 70% of all high-velocity features are deep penetration-tracks that contain unmelted, well preserved impactor residues. We also observe that the Shuttle practice of dumping some 75 liters of waste water every 3 days produces a readily detected cloud of co-orbiting solids and even droplets. Also, our efforts will contribute to the Stardust Discovery Mission, currently on its way to comet Wild 2. During comet encounter in 2003, freshly released particles will be captured with aerogel collectors for a return to Earth in 2007, where the collectors will be processed and curated in the Facilities for the Curation of Extraterrestrial Materials at JSC.

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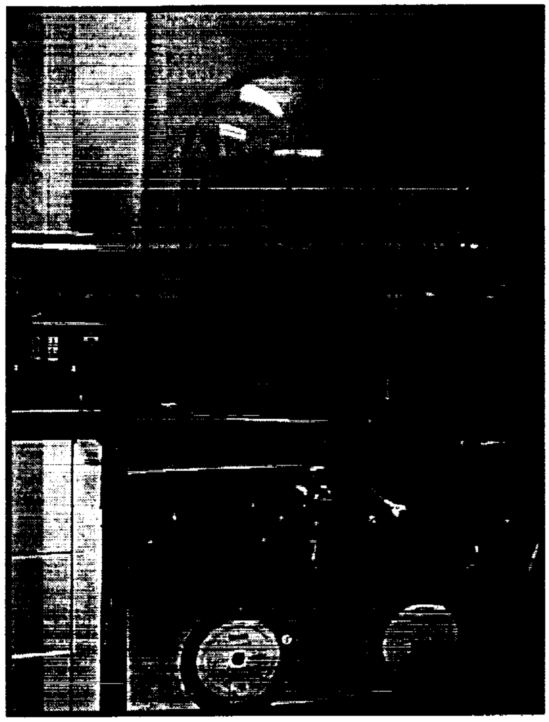

Flow visualization chamber used for evaluating methods to simulate, measure, and control Martian dust and wind environments.

Technology Category: Environmental

ENV-6 Mars Dust & Wind Environment Simulation, Measurement and Control

Background

HEDS missions to Mars require hardware certification to design environments. Environments with relatively well-known specifications such as atmospheric composition, pressure, and temperature have existing test facilities for verification. However, environments with relatively unknown specifications such as dust loading, dust precipitation, and wind velocity do not have test facilities to support verification activities.

Project Overview

This activity enables verification-by-test for hardware design environments by developing the facility capability and personnel experience to reliably measure Martian dust and wind environments while also evaluating alternative methods to control the respective environments.

The Energy Systems Test Branch has researched anticipated Martian environments and proposed test facility simulation requirements for the respective environments. Relationships have been established with experts in government, industry and academia to stay abreast of the latest developments with respect to anticipated Martian environments. Also, preliminary Martian dust and wind environments have been created at the bell jar level, enabling studies of environmental instrumentation and alternative generators.

The output of this activity result in improved planning for simulating full-scale environments in test chambers. One example comes from recent development testing of the Mars In-Situ Propellant Production Precursor Flight Demonstrator which made use of wind generation methods established from this activity to provide uniform atmosphere temperature within the facility chamber. To date, the Energy Systems Test Branch has established methods of generating and measuring dust and low wind environments using commercial off the shelf (COTS) equipment. Future activity will be oriented at controlling environmental parameters and improving test-to-test repeatability.

Benefits and Uses

The primary benefit of this activity comes from advancing NASA's readiness to provide reliable cost estimates as well as implement cost-effective verification plans for specified design environments.

Researchers from government, industry and academia preparing Martian experiment proposals routinely contact the Energy Systems Test Branch in order to fulfill their verification plans by making use of unique facility capabilities without incurring duplicative costs.

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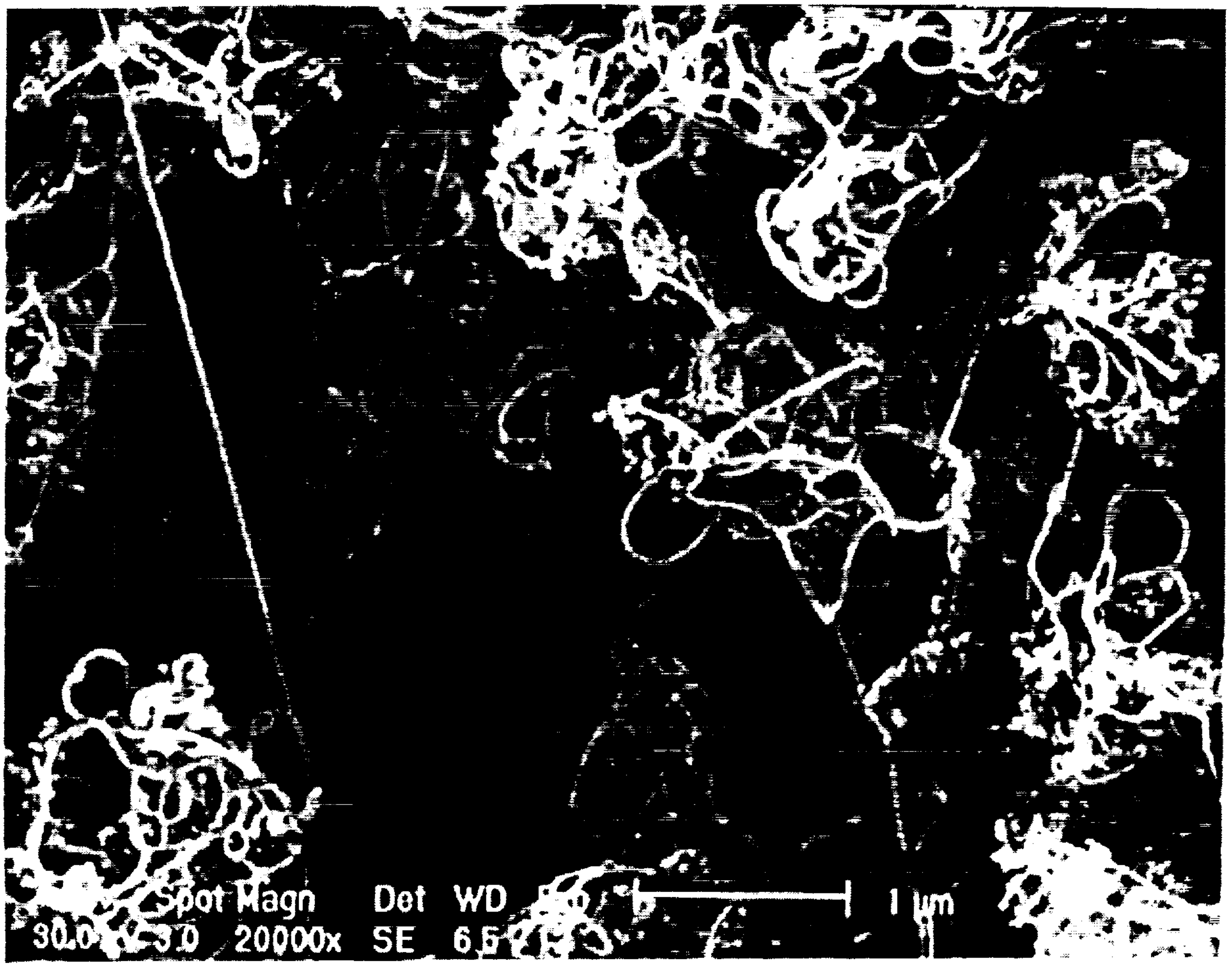
ADVANCED MATERIALS



This scanning electron micrograph of single wall carbon nanotubes produced at JSC shows only bundles of nanotubes, since the individual tubes are too small to be viewed at this magnification.

Technology Category: Advanced Materials

MAT-1 Carbon Nanotubes – Production and Applications

Background

Since the discovery of the Buckyball in 1985 at Rice University, the study of fullerenes has grown tremendously. Although the Buckyball has not resulted in the applications expected upon discovery, a new hope has been found in the 1990's with the discovery of carbon nanotubes. Specifically, single-wall carbon nanotubes (SWNTs) are not only the strongest material known today, but also possibly the strongest material ever possible. And that's just the beginning. SWNTs of the type made at JSC are also as electrically conductive as copper and as thermally conductive as diamond. This combination of properties make nanotubes an enormous interest in many fields including materials science, physics, chemistry, and all types of engineering. Specific NASA uses for nanotubes include advanced materials and composites, nanoelectronics and nanodevices, flat panel display, energy storage, and biomedical uses.

Project Overview

In January 1997, collaboration began between Johnson Space Center and Rice University for the production and application of carbon nanotubes. Nobel Prize winner Richard Smalley's research group was instrumental in bringing to JSC the ability to produce nanotubes using the double laser ablation technique. Now JSC has expanded the project from its early production to using diagnostic methods to study nanotube growth by studying the plasma plume in the laser system. Also, the project has set up an electric arc chamber for nanotube production, which is much simpler, cheaper, and faster than the laser process. However, the arc process produces nanotubes that are much less pure than the laser process, and are more difficult to purify. This purification is also done at JSC so that the nanotubes can be used for making composite materials. These tests of mixing and processing of composite materials are underway. The purpose is to produce materials with the highest strength-to-weight ratio ever produced.

Benefits and Uses

Within ten years, nanotube technology will be infused into many aspects of the scientific community including materials science, chemistry, physics, biomedicine, and electronics. In the much shorter time period of three years, nanotubes will start being used for applications such as conductive polymers and field emission arrays for flat panel displays. Hopefully, high strength materials will be developed within 3-5 years. Carbon nanotubes have such wide-ranging promise for applications as listed above that both government and industry will have large investments in this technology in the coming decades.

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MEDICAL

MED-1 Millimeter Wave Catheters for Treatment of Atherosclerotic Lesions

Background

The purpose of this project is to develop and test a millimeter-wave (94 Ghz) catheter for treating atherosclerosis, which can be commercialized by a catheter company. This treatment would replace angioplasty which has to be repeated in up to 50% of the patients.

Project Overview

Atherosclerotic lesions on coronary artery walls constitute the major culprit in heart disease which can lead, if not controlled, to heart attacks and an untimely death of cardiac patients. All of the treatment methods in use today result in either full or partial destruction of the superficial cell layer (endothelial cells) which induces an inflammatory response that acts to reduce the arterial lumin, a phenomenon called restenosis. Millimeterwave Angioplasty (MA) holds the promise of permanent cure coupled with a reduced restenosis. Unlike other methods, which rely on mechanical trauma, excision, or perforation to achieve the desired widening of the artery, MA uses electromagnetic (EM) wave heating of the arterial walls. By judicious selection of excitation frequency, radiated power level, exposure interval, and antenna beam design, it is theoretically possible to preserve the first 100 μm of the intima while eliminating the deeper fat in the media. At present, a prototype has been built and will be tested in the laboratory in the fall of 1999.

Benefits and Uses

Permanent Cures: Atherosclerotic lesions can be removed with a single application. This is in contrast to Balloon Angioplasty treatment that may have to be repeated.

Better: It will also result in reduced restenosis when compared to any other method in use today.

Non-Traumatic: The patient requires only a small incision where the catheter is inserted into the groin. The patient stays alert and reasonably comfortable during the procedure.

Cost effective: Since lesions are eliminated with one application, the patient's projected cardiac care costs are markedly reduced and his quality of life is considerably improved after the procedure.

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The Telemedicine Instrumentation Pack (TIP) being demonstrated at Lame Deer Clinic on the Northern Cheyenne Reservation in Montana. The TIP comprises video imaging for eye ear, nose, throat, and skin; biomedical monitoring capabilities for ECG, SpO_2, blood pressure, and heart rate; and an electronic stethoscope for heart, lung and bowel sounds.

MED-2 Terrestrial Application of the Telemedicine Instrumentation Pack

Technology Category: Medical

MED-2 Terrestrial Application of the Telemedicine Instrumentation Pack

Background

The Telemedicine Instrumentation Pack (TIP) was developed to extend the medical support capabilities on board the Shuttle and the International Space Station. The TIP is packaged into a single case weighing 36 lbs with dimensions of 19"x16"x9" and represents a portable "multimedia doctors bag" encompassing several medical instruments interfaced to an embedded Pentium-based computer. The computer has the capacity to gather data from these various instruments and transmit these data via a variety of communication modes. Depending on the communication bandwidth available, the TIP can acquire and transmit data in real time, just in time, or in a store and forward mode.

Project Overview

Two TIP units were constructed for use by the JSC Technology Transfer Office. The first of these units was delivered to the Partners in Health Telemedicine Network (PHTN), a collaborative project based in Billings, Montana. PHTN has developed and is currently implementing a plan to utilize the TIP in extending health care services to inactive diabetic patients on the Northern Cheyenne reservation. The first phase of operation will utilize the TIP to perform home examination of the patients and store-and-forward data transmission to the consulting physician. The Medical Operations Branch has worked with the PHTN to train clinicians and to identify aspects of the project that has co-lateral benefit for NASA Medical Operations. Among these benefits is the opportunity to have the TIP deployed in a truly clinical context thereby permitting an evaluation of the clinical efficacy of the TIP instrumentation and communication capabilities. In addition, valuable information will be forthcoming on the ergonomics and human factors of the entire system, and the robustness and reliability of the TIP under conditions of repeated daily use. The first patient data will be collected beginning August 1999. Completion of the Technology Transfer agreement with the PHTN is scheduled for August 2000.

The second of the two TIPs is to be used by Christus Health Spohn Memorial Hospital in Corpus Christi, Texas. The TIP will be installed into a Family Health Center (FHC) located in Robstown, 20 minutes west of Corpus Christi. The FHC is linked to the main Hospital campus via a wide area network. Consequently, with the TIP connected to this network, there is the capability for both real-time and just-in-time modes of telemedicine, as well as store-and-forward activity.

Benefits and Uses

The TIP offers the capability for performing portable and relatively inexpensive telemedicine. As such, the TIP represents a new state of the art in telemedicine instrumentation able to operate without high bandwidth communication lines, expensive encoders/decoders, and installation in dedicated facilities. These benefits offer health care providers a new mode of delivering health care in remote and/or underserved regions. The current test and evaluation of the TIP under the two Technology Transfer agreements allows NASA to gather valuable information to enable future enhancements of the TIP. In conjunction, the program demonstrates to the health care community the advantages afforded by this technological innovation.

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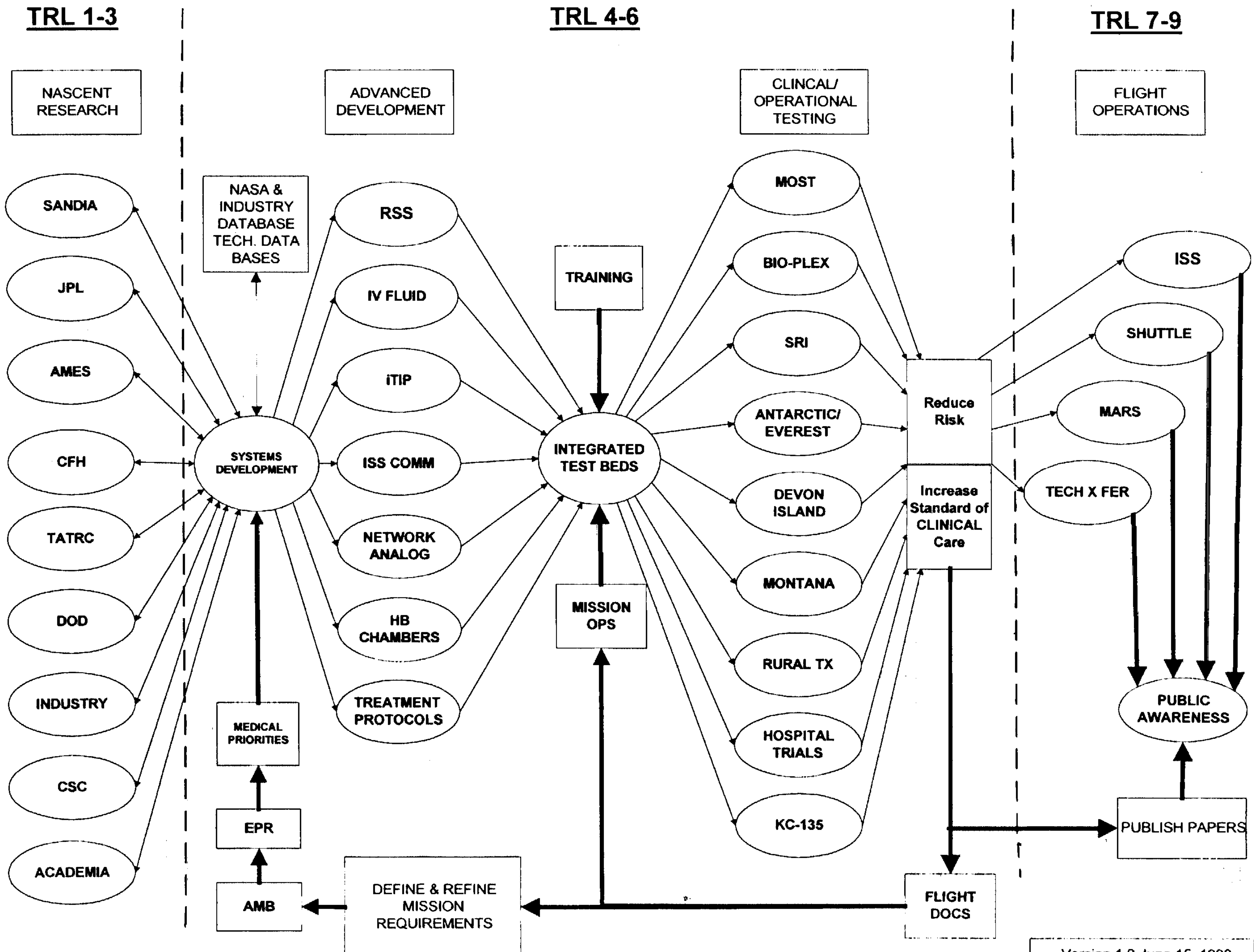
CCCDP ARCHITECTURE



Version 1.0 June 15, 1999

MED-3 Clinical Care Capability Development Program

Background

The Clinical Care Capability Development Program (CCCDP) addresses the limitations of current operational space medical systems, procedures, and protocols. Recent mishaps on the Mir space station illustrate the potential magnitude of clinical space medicine emergencies and highlight the deficiencies in this arena. The CCCDP defines the scope and practice of medical care needed for each phase of human space flight based upon probabilities derived from the Longitudinal Study of Astronaut Health, analog populations, and expert opinion. The CCCDP implements an end-to-end process that transitions raw technology concepts into operational space systems that increase the standard of medical care in flight and reduce the risk to both the mission and the crew.

Project Overview

The purpose of the CCCDP is to design, implement, and manage a comprehensive health care program for space flight to include health monitoring, prevention, and intervention for all mission phases. Specifically, the CCCDP is responsible for defining the medical care requirements for all mission types and for recommending the level of training necessary for the Crew Medical Officer per mission risk level. The CCCDP is also responsible for providing leadership and expertise in the positive evolution of space medicine. The CCCDP evaluates and continually updates the clinical care standards available for each mission and the clinical training of each level of medical care provider. In addition, emerging clinical technologies under development will be evaluated for their potential to enhance the standard of care during missions.

The CCCDP manages the development of several technologies including integrated telemedicine systems, advanced respiratory support systems, compact hyperbaric chambers, compact ultrasound, intravenous fluid formulation and administration systems, global medical communications, and non-invasive real-time blood analysis and imaging technologies. The maturity of each project depends on the scheduled implementation and overall mission phase. The extreme reliability needs of space flight dictate that new technologies or medical protocols are validated via terrestrial test beds or environments analogous to space flight before becoming operational in flight. As a key characteristic of the CCCDP, collaboration with academia, industry, and other federal agencies is mandated to eliminate redundant technology development and foster relationships for future endeavors. A network of technologists and researchers allows the CCCDP to identify efforts driven by commercialization, efforts conducive to partnerships, and efforts NASA must fund independently in order to satisfy mission goals at an acceptable level of risk.

Benefits and Uses

The technologies cultured via the CCCDP process will create highly integrated, reliable, and intuitive medical solutions that optimize crew training requirements and vehicle power, data, and logistical resources. These same medical systems could be used terrestrially when patient and healthcare provider are geographically separated yet connected via a telecommunications modality. This may include prisons, mining and oil operations, the maritime industry, military operations, remote expeditions, and mass casualty emergencies. Licensure of these medical systems would be appropriate if a viable business model and regulatory compliance is demonstrated.

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PHOTONICS

Hybrid Vision Laboratory

2 Civil servants — 8 patents
3 Contractors — Approx. 100 publications

Major Disciplines:

Digital and optical image processing

Prime applications:

Small, fast vision systems for space robotics

Ancillary applications:

Short-term consulting to other JSC functions

Examples of consulting w/in JSC

- Pyrotechnic optics for X-38 [*EP*]
- 'Spoiled' retro for TRAC [*ER*]
- Digital image processing for Station
  - Space Vision System [*MV*]
  - ORU target surveying [*ER*]

Vigorous SBIR program

Active: analog "correlator on a PC card"

Recently completed: aperture coding for extended focus range of a camera

Optical information processing

- Coherent light carries an image
- Correlation-based image information extraction
- Advanced methods and devices
- Military associates:
  - Navy (Naval Surface Warfare Center)
  - Army (ARL, AMCOM)
  - Air Force (Rome Lab)
- University associates: Carnegie Mellon, U.Mo/KC, CU/Boulder, others

Facilities

- Full optics lab
- Some specialized digital equipment
- Optical correlator test bed
- Model positioners for 'truth' imagery

Technology Category: Photonics

PHO-1 Hybrid Vision

Background

Optical information processing (OIP) uses light to carry information and various photonic devices to affect how the information appears as the light propagates. The most common example may be the watch on your wrist; information is impressed on the arriving light field by the LCD, which is electrically modified by the circuitry within the watch. In more exotic examples, extremely high data rates are processed in vision or communication applications. In some instances the photonic implementation operates to an advantage over digital or electronic processing (e.g. all-photonic switching of fiber optic signals, or two-dimensional convolution processing of an image).

Project Overview

The Hybrid Vision Laboratory at NASA's Johnson Space Center has been developing spatial light modulators, optical correlators/convolvers, electrically driven holograms, and optimal pattern recognition theory since the mid-1980s. We hold several patents in the area including implementation of fully complex modulation (phase and amplitude, independently), holographic control of light focus for addressing multilayer optical information storage, and others. We have operating computer code that implements our state-of-the-art optimal optical filter theory, including optimizing the Rayleigh quotient and the Fisher ratio that are ordinarily found only in digital computation pattern recognition.

Our laboratory methods include area characterization of the spatial light modulators that are at the heart of light control; we think we are the only group carrying out full-face fully complex quadrature interferometric modulator characterization. We have also developed and patented a method of using those measured characteristics to control the focal depth and focal pattern of light, so that non-mechanical (hence faster) adjustments may be made in addressing optical information storage media such as multilayer CDs. With companies under contract to the Government, we are working to transition these technologies into commercial practice, while fostering further growth in both Government and contractor abilities.

Benefits and Uses

One JSC patent (available for license) describes a method for tracking motions of the eyeball during laser procedures such as retinal photocoagulation. The method would permit a surgeon to work closer to the fovea (the point of highest resolution – the point of direct vision) by maintaining closer control of exactly what part of the eye is being hit, thus minimizing collateral damage, and also shutting down the surgical laser far faster than a human operator can when the tracking is lost. Another JSC patent (available for license) describes how separate layers of compact disks can be addressed without moving mechanical parts, potentially speeding up the rates at which information can be extracted from them. The devices and architectures being developed under contract can speed up machine vision to the point of doing literally hundreds of full-frame image correlations per second, thus inferring (for example) part identification and orientation on a production line at full video frame rate. Another JSC-patented technique permits reconnection of light-borne information switching within the vertical retrace time of a video frame, without changing the information from light-borne to electronic and back to light-borne form. All these applications are available for commercial use.

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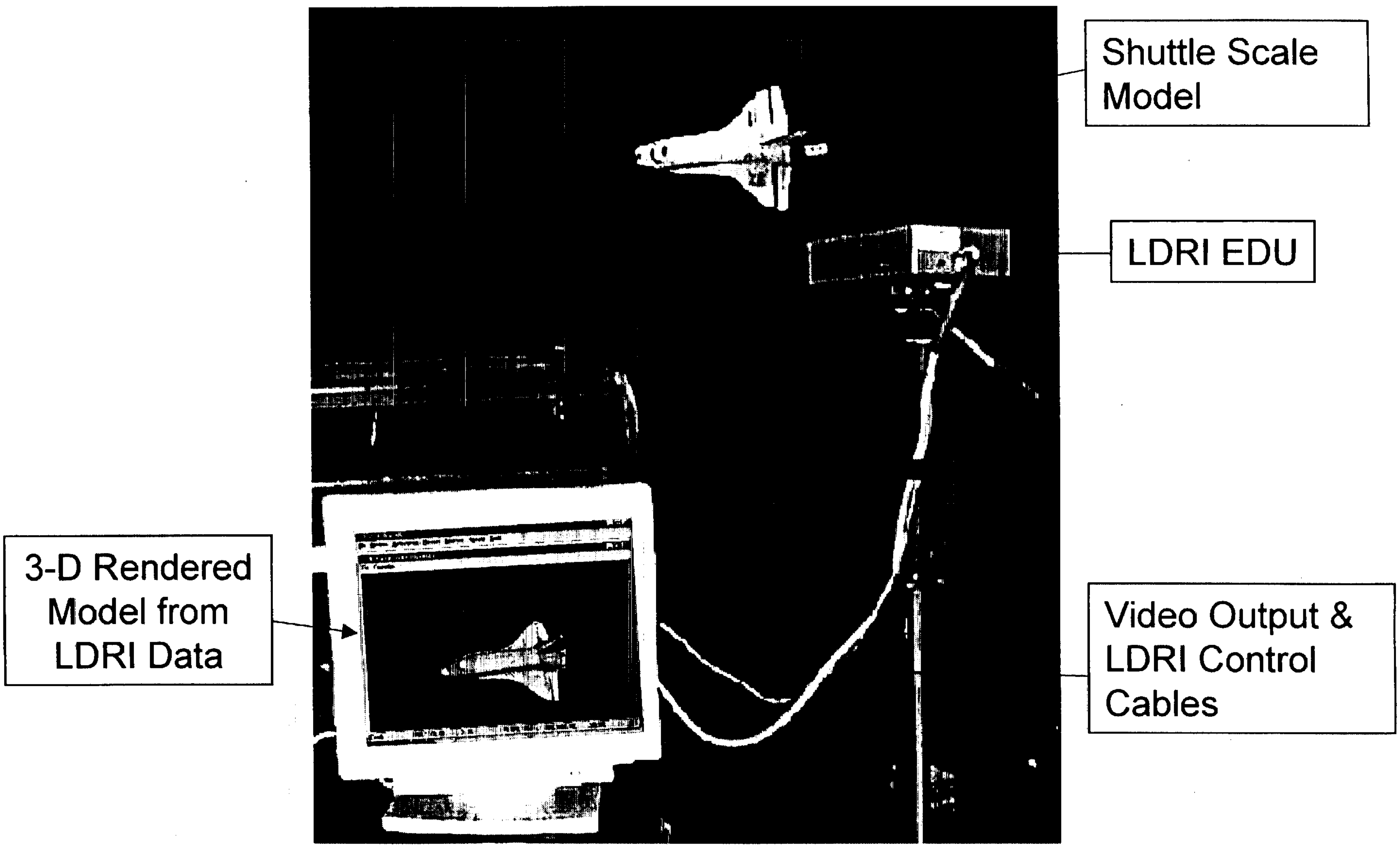

LDRI EDU Demonstration

Technology Category: Photonics

PHO-2 LASER Dynamic Range Imager (LDRI)

Background

Static and dynamic measurements are key to validating on-orbit assembled and deployed space structures but are very challenging to obtain with conventional instrumentation. The complexity of these space structures demand that large numbers of locations be measured simultaneously. Photo-grammetry measurements have limited utility due to the field of view available when zoomed in to obtain high resolution. Laser vibrometers can scan to address one point at a time, but this is not sufficient to address the great number of measurement locations during structural-dynamic motion decay.

LDRI fills the "hole" in the on-orbit structural-dynamic measurement capability. Sandia National Labs Scannerless (LASER) Range Imager (SRI) technology was selected to create range images at video rates, because each pixel, representing an individual range measurement, can be used to characterize the structural-dynamic response or static structural conditions. This provides data with unlimited options for combining the multitude of measurements taken of the entire field of view for each digital frame.

Project Overview

The purpose of the project is to demonstrate LDRI's new measurement capabilities on the Space Shuttle and to obtain measurements of the International Space Station structure. Secondary objectives include ground and on-orbit demonstrations of LDRI applications to other Human Exploration of Space projects such as robotics and extravehicular activity crew member assistance, space vehicle proximity operations and inspection, planetary rovers and landers, and potentially particulate density/flow measurements.

The LDRI Infrared LASER beam is amplitude-modulated and then diffused over the field of view. The LDRI receiver filters all but the reflected energy from the scene at the LASER wavelength (850nm) and then amplifies it with an image intensifier coupled to a charge-coupled device. The resulting black and white intensified video images and the time-of-flight related phase information are used to create real-time range digital video images. These images provide instant depth perception to the operator in almost any lighting condition. Calculations can be performed in real-time to produce range, range-rate and orientation to an object. Post-test calculations can provide high resolution 3-dimensional static geometric models and surface maps, 3-dimensional dynamic models which provide modal parameters and mode shapes for low frequency vibration.

Currently, JSC has a working engineering unit for application testing in its labs. A spaceflight unit is under development which will operate on the Space Shuttle orbiter to image the dynamic response of the giant Space Station solar arrays after a series of thrusters are fired. The next step is to reduce the size of a shoe box to about ¼ that size, but with higher resolution and frame rates as well as more internal processing capability for use with navigation/robotics applications.

Benefits and Uses

LDRI is a revolutionary imaging and measurement technology that can help the space program reduce the number of sensors needed on space vehicles as well as provide structural-dynamic measurements which have been impossible up to now. It represents a leap forward for military autonomous space and robotic sensors and new opportunities for the soldier to identify and characterize threats. LDRI could become the first scannerless LASER vibrometer, the first truly 3-D video camera, and the next generation robotic sensor for manufacturing and inspection. University and research institutions can use the digital imagery for documenting human, animal, fluid and structural testing by range imaging the resulting motion.

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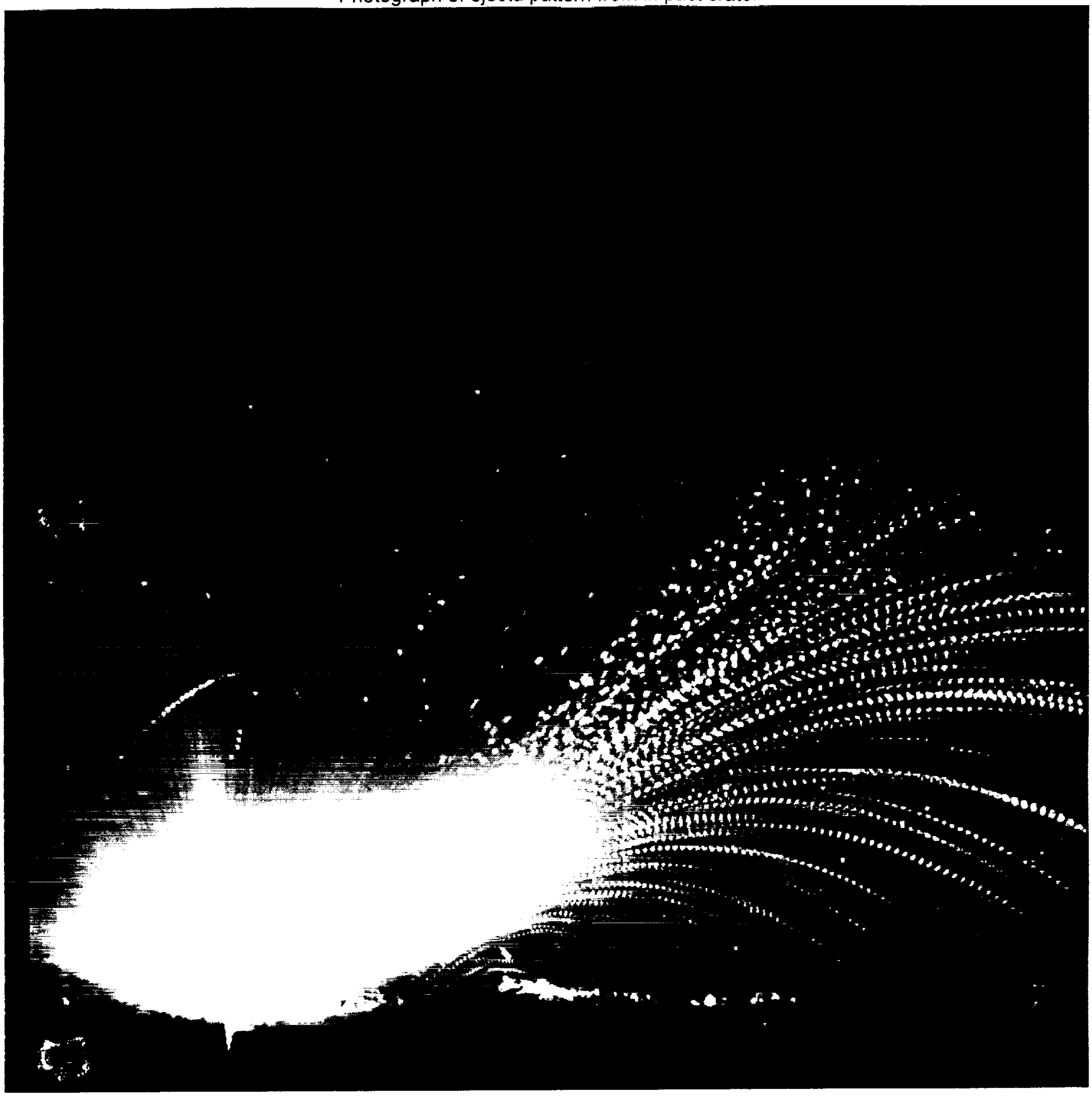
Photograph of ejecta pattern from impact crater



PHO-3 Ejection - Velocity Measurement System

Background

Impacts affect the surfaces of planets, including the Earth, in a variety of ways. Some of the more obvious and important are related to ejecta, which is the material thrown out of the crater through action of the shock wave created by the collision. Deposits of ejecta, along with the hole that is the crater, constitute most of the topography created by an impact. Meteorites arrive at the Earth as fragments of ejecta from asteroids, Mars, and the Moon. To understand impact craters, it is important to understand the process of ejection.

Project Overview

Impact craters are created in laboratory settings on a regular basis, and ejecta from those impacts can be photographed easily. Unfortunately, measurement of the velocities and trajectories of ejected fragments historically have been made difficult in the photographic confusion caused by huge numbers of fragments ejected in all directions. A method devised by a group at the University of Dayton in the 1970's has been modified and updated at JSC with 1990's technology to study the ballistics of ejection.

Laser light is passed through a cylindrical lens, generating a "sheet" of high-intensity illumination; this sheet of light can be directed through the impact point in a plane perpendicular to the surface of the target and parallel to the focal plane of a camera. A waveform generator can then be used to modulate the laser's output into a timed series of flashes. A cooled-CCD camera then takes a time exposure of the cratering event as it is illuminated by the flashing laser. The resulting stroboscopic photographs thus provide timing (the time between flashes of the laser is known, having been programmed) and geometric information on trajectories of ejected fragments (the shapes of which can be measured easily). Data obtained with this technique have shown, for example, how and where state-of-the-art, quantitative approaches to cratering phenomena are not yet complete.

Benefits and Uses

This approach to measurement of particle motion can be used in a variety of situations in which motion occurs in a plane. Convection cells, for example, are well suited to this sort of study. Spray from nozzles or rocket motors, particle motion in wind tunnels, and sedimentation are other examples of processes that could be examined in detail using this technique. The principal cost of such a system is in the cooled-CCD camera, which is necessary because of the time exposures used in collecting the data; thermal noise in uncooled cameras would lead to image degradation. The color and output intensity of the laser are dictated by the characteristics of the subject material.

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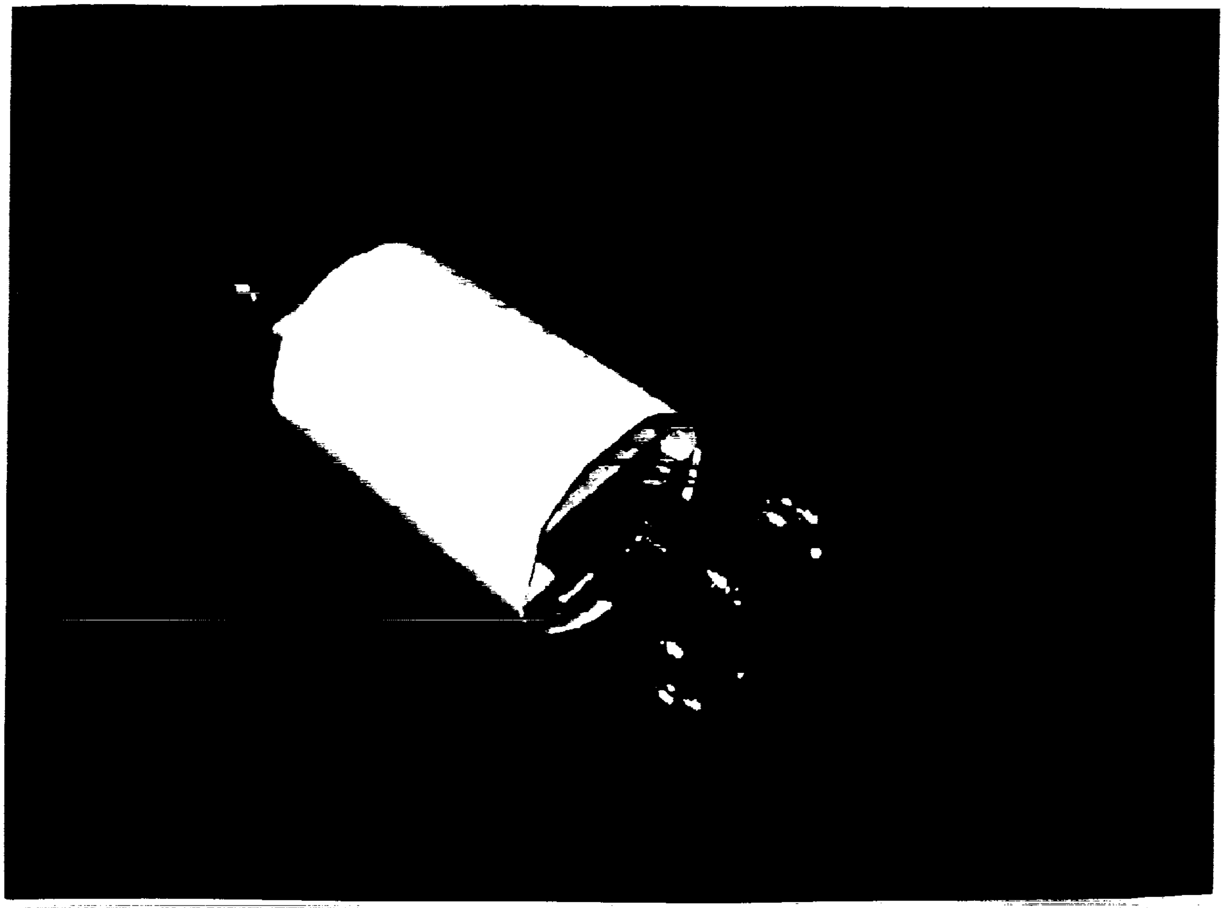
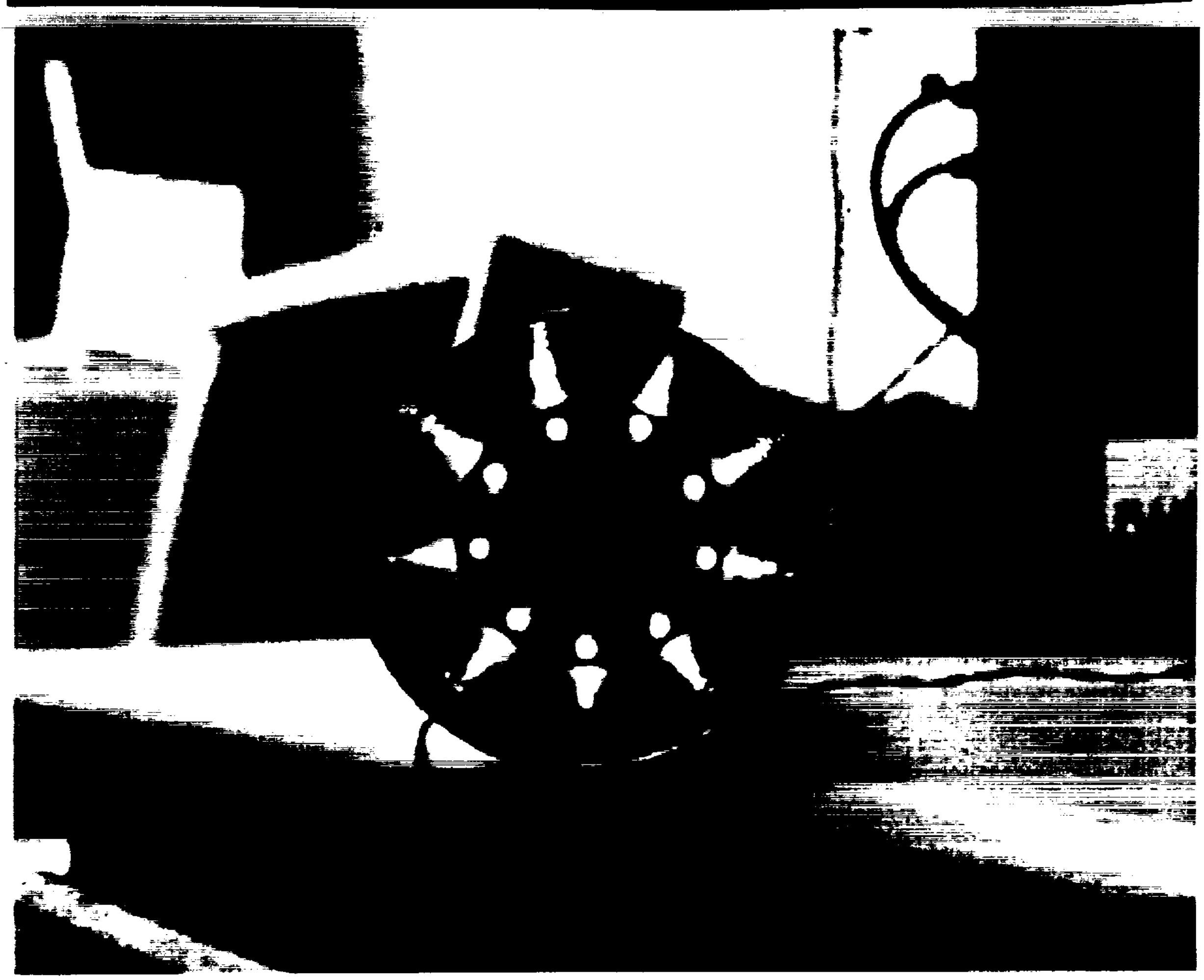
COMPUTER SOFTWARE





Technology Category: Software

SOF-1 Video Mosaicing for Pipeline Inspection

Background

Visual inspection of gas pipelines is performed using small camera systems with moving optics that permit the operator to pan the camera from side to side for either a down pipe view or a view of a portion of the side of the pipe wall. The moving optics expand the narrow field of view of the camera by allowing the operator to pan and tilt the camera's line of site for down pipe views or to rotate and look at the pipe wall. There is a desire to increase reliability by eliminating the need for moving parts and to provide simultaneous down pipe and full circumference radial views.

Project Overview

The purpose of this technology is to apply computer vision techniques, known as video mosaicing, to enhance graphic views for visual inspection of gas pipelines. The vision system is capable of providing, in real-time, simultaneous forward views and integrated full circumference radial views of the pipeline under inspection. The video mosaicing software has been specifically designed for imaging a surface that is cylindrical. A wide field of view camera lens is used to capture down pipe images as well as radial views of the pipe wall. The wide field of view lens captures a distorted image, which must be re-mapped and re-integrated via software into a contiguous picture of the pipe wall. A prototype camera system has been assembled and initial software developed to re-map the distorted pictures and mosaic them into a contiguous image of the interior of the pipe wall.

Potential enhancements include promoting visual pipeline inspection to supervised inspection (a precursor to fully automated inspection). One scenario is for a visual pipeline inspection system to provide enhanced graphical displays, possibly with highlights on potential defects found within the pipe or with an audible alarm to alert operators to a suspect area within the pipe.

Benefits and Uses

There are a large number of companies offering visual inspection equipment for use in pipeline inspection. Almost all of them, to our knowledge, only offer unprocessed video images for human inspection. One major drawback of this approach is that it relies completely on the human operator to perform pipe inspection by viewing video images either in real-time or from pre-recorded tapes over a long period of time. Fatigue induced by long viewing (of mostly featureless images) makes human inspection less reliable as well as more labor intensive. We believe that the potential of visual pipeline inspection can not be realized without exploiting techniques well developed in computer vision. With enhancements from computer vision techniques, visual pipeline inspection can be promoted to supervised and/or automated inspection.

This technology is still under development. Re-mapping the distorted images and mosaicing into a contiguous sequence of radial views has been performed successfully as a camera system is being moved down a pipe. The application of this technology can be applied to internal pipe inspection of four-inch diameter or larger pipes.

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Technology Category: Software

SOF-2 Video Analysis

Background

In addition to being subjected to the risk of collision with pieces of debris in orbit, spacecraft are at the mercy of meteor showers, that is, the risk of being bombarded by micrometeoroids. The meteor showers that have recently exhibited the most danger to spacecraft are the Persieds, occurring each August and was most prevalent in 1994, and the Leonids, occurring each November and predicted to storm in 1999. The November 1998 Leonids Shower was videoed at the Johnson Space Center (JSC) in Houston and at the JSC observatory in Cloudcroft, New Mexico. The output of this effort was a meteor hourly rate and the generation of a meteor mass distribution. The mass distribution generated by the Leonids video data exhibited a difference from the theoretical model used as input for risk assessment calculations associated with Space Shuttle missions. In the past, the model assumed a meteor mass distribution. The 1998 analysis along with analysis planned for the 1999 Storm will either verify the assumptions of the model or show that a modification is warranted.

Project Overview

The result of the analysis of the 1999 Leonids Meteor Storm is expected to verify the model now being used or indicate where a modification is warranted. The equipment used in both locations is a low light level video camera and a hi - 8 video recorder. The camera at JSC - Houston is mounted on a telescope mount, whereas a camera tripod is used at Cloudcroft.

The 1998 analysis was performed using the JSC Video Digital Analysis System (VDAS) laboratory, but the 1999 analysis will be performed by a newly developed Meteor Analysis System because the capability used in the VDAS lab was retired due to obsolescence.

Because the data gathering observations depend on the weather, two primary sites are being used, JSC - Houston and Cloudcroft. As backup, a JSC Astronomical Society member has volunteered to video the Leonids in the Canary Islands, and another volunteer plans to video them at an observatory southwest of Houston.

Benefits and Uses

The benefit of the proposed analysis is the verification of the present model or its modification. In addition, a study of the variations in the direction of the Leonids radiant is planned. This study will aid in the accuracy by the modelers in their prediction of the severity and densest location of the Leonids Meteors. These techniques might be able to be extended to other meteor showers, and therefore the risks of commercial as well as government spacecraft being damaged by meteors can be more accurately predicted.

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For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

Effects of Lighting on Human Performance in Training

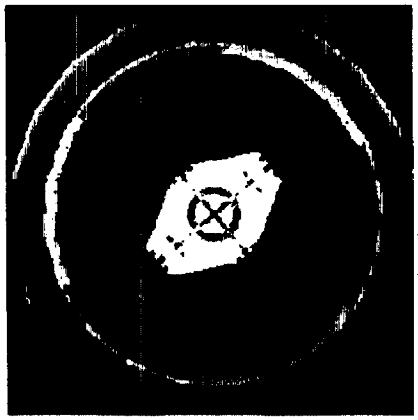

Fig 1. Docking target model with no shadow or glare

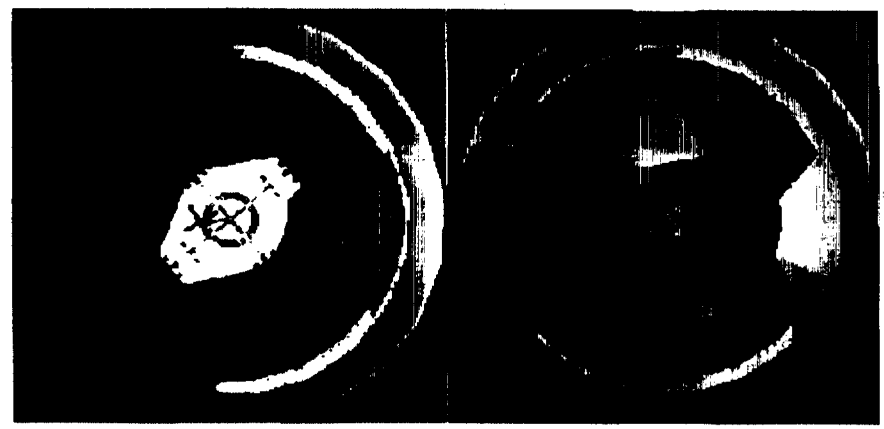

Fig 2. Docking target model with shadows and glare.

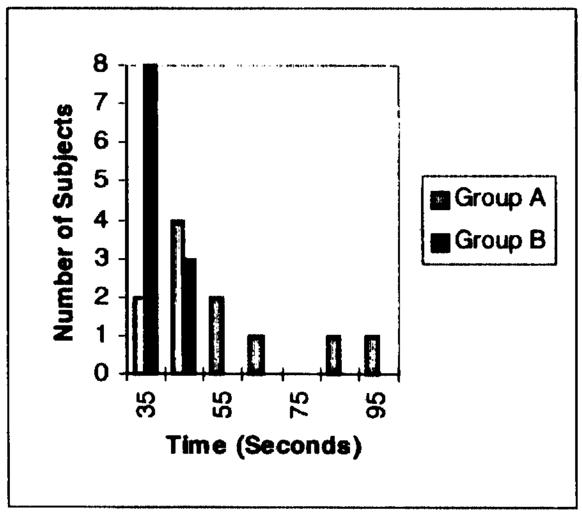

Fig 3. A comparison of times to complete the actual task. Group A trained without lighting. Group B trained with lighting.

Technology Category: Software

SOF-3 Measuring the Effects of Lighting on Human Performance in Training

Background

Many of the tasks performed by astronauts while in orbit, such as the deployment of payloads, depend on obtaining visual cues, either from a camera image or direct viewing. Direct exposure to intense sunlight and to rapidly changing sunlight direction makes crew response to high contrast shadows and variations of incident light angles an essential part of carrying out mission operations. Training with mockups and lighting hardware has received positive response from crews prior to missions involving docking. However, much of the crew training is done with computer simulators using conventional shaded geometric models. These models do not simulate actual lighting environments, which include effects such as shadows and glare. The purpose of this project was to compare the effect of different types of training images on actual task performance. Specifically, the effect of computer task training with accurate lighting images, shadows and glare were compared to computer task training with basic shaded models with no shadows and glare effects.

Project Overview

To compare task performance with respect to different types of training, a simple alignment task, similar to the alignment of the orbiter with the Mir docking target, was used (figures 1 & 2). Two different experiments were conducted with two groups of subjects: those trained without lighting and those with lighting. The first experiment emphasized alignment accuracy only. Subjects were allowed any amount of time needed to obtain the required alignment. Objective results were not conclusive but subjects who trained with lighting images felt more confident 1) that their test results were accurate, 2) that their training would generalize to other tasks, and 3) that the training was reasonably realistic. The second experiment emphasized alignment accuracy and alignment response time. In this case, subjects trained with lighting (Group B) as part of the scenario had a significant advantage (average execution time 34.9 seconds) over those who did not (Group A with average execution time of 40.7 seconds). See figure 3.

Benefits and Uses

When time constraints are imposed on a task, training with lighting effects improves task performance without sacrificing accuracy. In addition, subjective evidence reveals that subjects who trained with lighting effects had lower stress levels when executing the actual task. While computer technology is not yet able to generate "real time" ray tracing images for training, lighting conditions can be modeled for specific cases using existing computer hardware lighting parameters and special case shadowing effects. The results also support the use of lighting and illumination techniques for non-computerized image creation using mockups and artificial lights.

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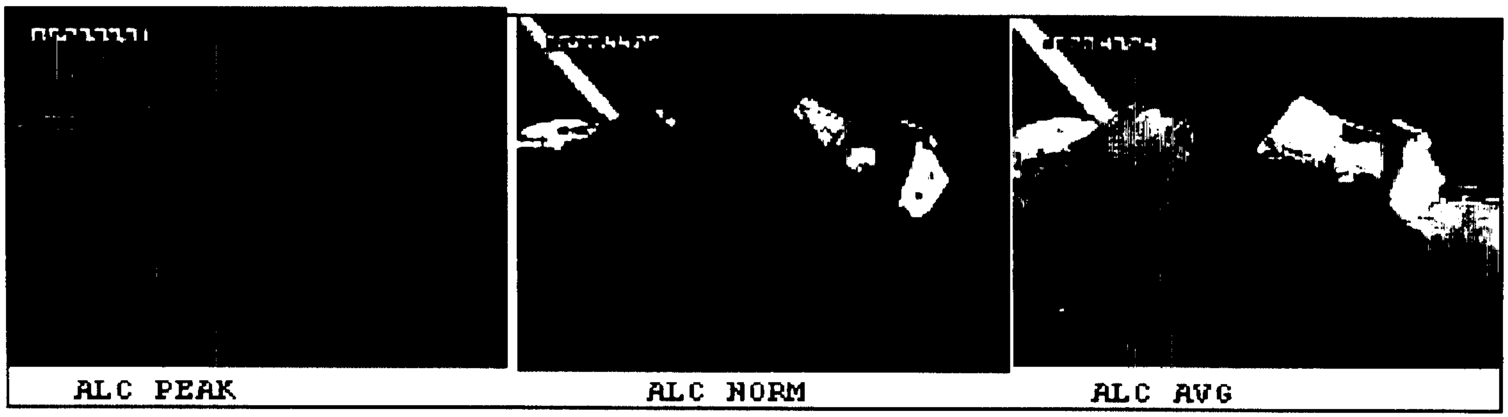
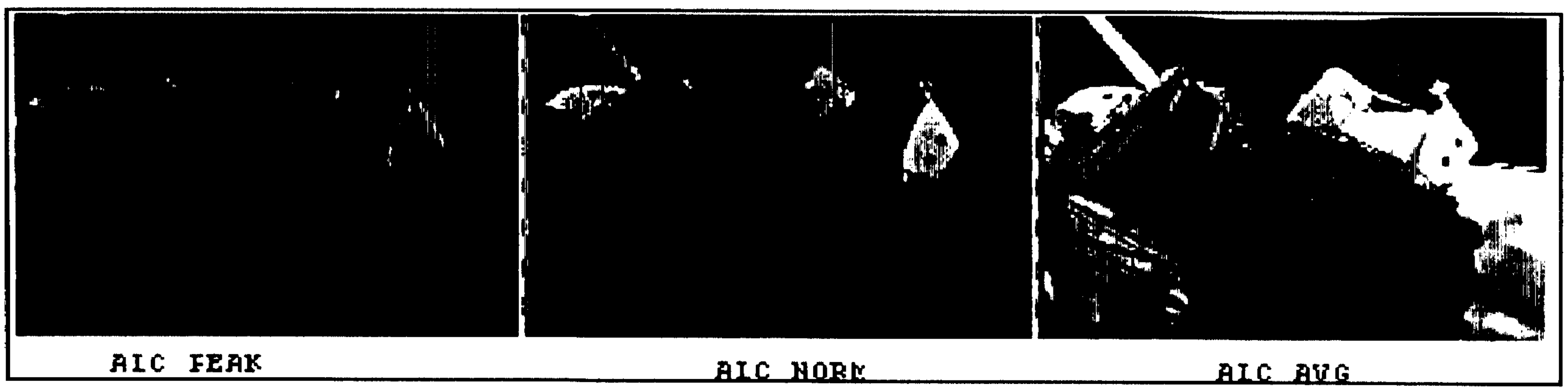
Camera Images from Luminance Maps - Figure 1

STS-74 Downlinked Video





Predicted by Model

Technology Category: Software

SOF-4 Camera Images from Luminance Maps

Background

The purpose of this project is to develop and validate computer models of the Shuttle TV cameras based on the scene illumination and the camera parameters such as noise, gamma, and gain. The input to the camera model is an accurate computer calculation of the scene luminance, i.e. the amount of light reflected from objects in the scene into the camera lens. Such calculations can be very accurate but are slow (~20 minutes) to generate. This computer model of a Shuttle TV camera will allow pre-flight prediction of lighting conditions for camera based operations.

Project Overview

Post processing techniques of luminance maps created by a physically based lighting program were able to model the camera parameters of Automatic Light Control (ALC) and gamma control (image transfer function) for the CTVC (Shuttle color camera). To model ALC, the luminance map is scanned for a specified region which does not vary in luminance more than a designated amount determined by the ALC settings of average (AVG), normal (NORM) or peak (PEAK). A scale factor is then calculated that will display the average luminance in this area as the average brightness in the image (128 on a color scale between 0 and 255). This scale factor is applied to the entire image (Figure 1). The light entering the camera is displayed by controlling the CTVC camera with two gamma mode settings, GAMMA BLACK STRETCH and GAMMA LINEAR. For gamma control, only the camera's influence on the transfer function was modeled. Influences on the display from monitors and printers were not considered in this project. To validate results, computer generated images were compared to ground based images created with CTVC camera and lights. Video images broadcast from Shuttle were used for comparison as well.

Benefits and Uses

An accurate computer based camera model will allow preflight lighting analysis to predict the best times during an orbit for camera viewing of a specific activity. Such analysis is critical to mission success for operations that depend on camera viewing. Quick assessment of lighting impacts due to flight schedule changes can also be provided with this predictive camera model. For example, the performance of the camera based Space Vision System (SVS) during Space Station assembly, will depend on good camera images during the Shuttle berthing operations for Station assembly and pre-launch camera selection and location can be optimized for examination of critical components while on orbit.

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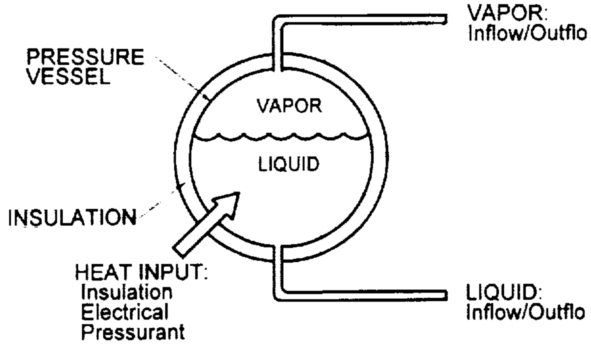
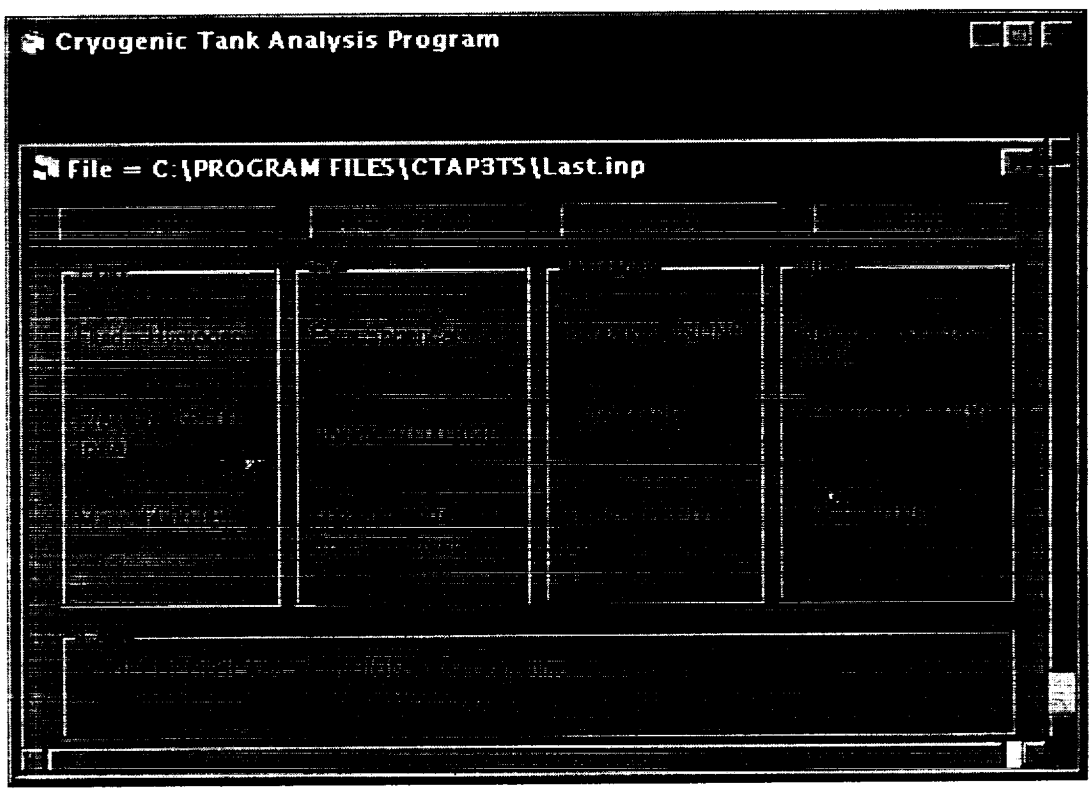
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.



Basic schematic of cryogenic storage system.



CTAP input display.

SOF-5 Cryogenic Tank Analysis Program

Background

The process of designing a cryogenic storage system requires a series of detailed analyses to compute the thickness of the pressure vessel, the required amount of insulation to achieve the desired heat leak input, and the sizing of heater or gaseous pressurization systems to expel the cryogenic fluid at the desired rates. This is often an iterative process. The Cryogenic Tank Analysis Program (CTAP) was developed to provide an easy to use software tool that would allow the design engineer to quickly determine the effects of varying the design parameters while investigating the conceptual design of a cryogenic storage system. The user can input design parameters in a spreadsheet like environment and select from a number of operating scenarios to perform both steady state and transient analyses on the proposed system.

Project Overview

Technology Applications, Inc. (TAI) was awarded a Small Business Innovative Research (SBIR) grant to develop a demonstration version of the CTAP software. They developed a Windows based program that allows the user to input a wide range of design parameters such as type of cryogenic fluid, size and shape of storage tank (spherical or cylindrical), type of insulation system, type of pressurization system (gaseous helium or electrical heaters), and the desired mission profile (flowrate versus time). The CTAP software can be used to develop the preliminary design of a storage tank and analyze its performance during the entire mission. CTAP is currently being used by Johnson Space Center engineers in the design of cryogenic storage tanks for propulsion systems. The design of the cryogenic tank and the gaseous helium pressurant tanks is developed initially using the CTAP software while the design is still in the conceptual stage. TAI is pursuing follow-on funding through the SBIR program to take the CTAP from the demonstration level to a final product that can be marketed commercially.

Benefits and Uses

The CTAP software can be used to quickly develop a conceptual design of a cryogenic storage system. It can also be used to train new design engineers on the parameters that need to be considered in the design and operation of a cryogenic fluid storage system. Since the CTAP software was developed under an SBIR grant, the software developer, Technology Applications, Inc, retained sole marketing rights.

For further details contact:

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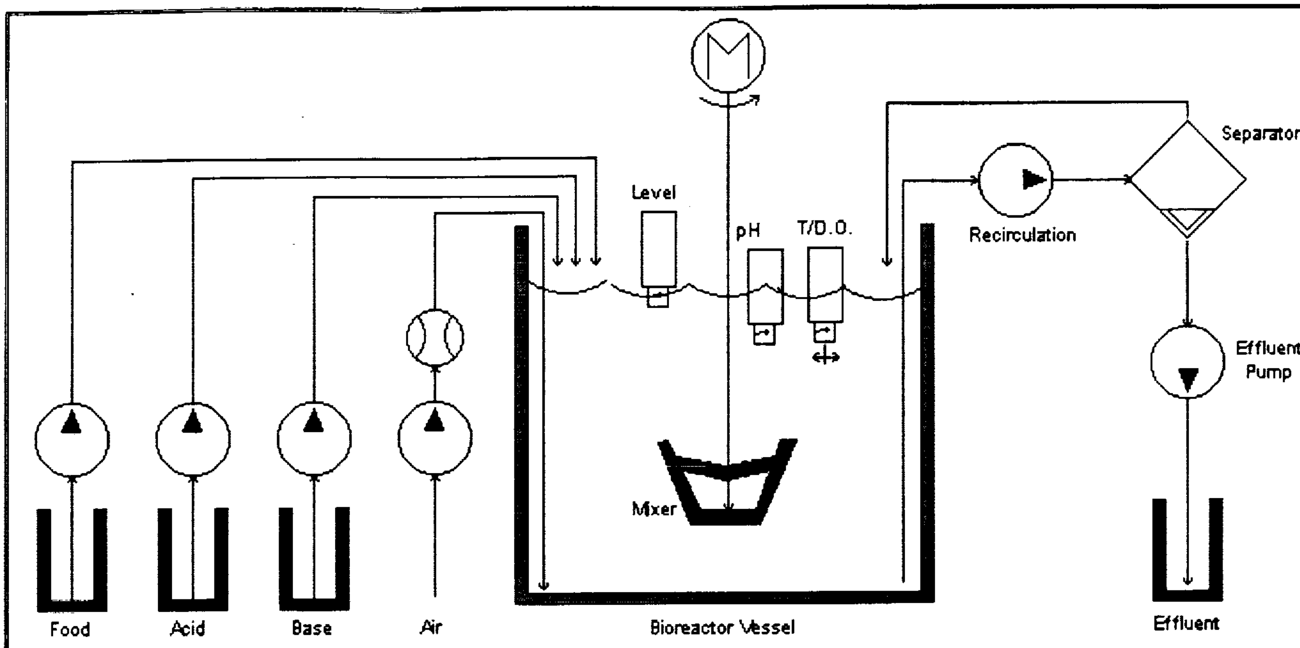


Figure 1 Screen shot of Schematic Editor showing structure of Magnetic Activated Sludge Reactor.

Technology Category: Software

SOF-6 Autonomous Fault Diagnosis and Recovery for Advanced Life Support Systems

Background

The Advanced Life Support (ALS) systems being developed for long-term manned missions are complex and characterized by a lack of sensors and redundancy. Diagnosis of and recovery from faults within them will require deliberative analysis and human intervention. On the other hand, remoteness and economy will require that crew members have a high degree of self-reliance and autonomy from ground support. These issues demand technologies for reliable automation of health maintenance activities that can efficiently call upon the crew to conduct inspections and repair operations. Techniques that reason from structural and behavioral models of the ALS system are needed to ensure maximum coverage of faults, including unanticipated faults. Efficient use of experiential knowledge is needed to ensure timely response. Handling of unanticipated contingencies also requires the capability to dynamically generate recovery and repair plans.

Project Overview

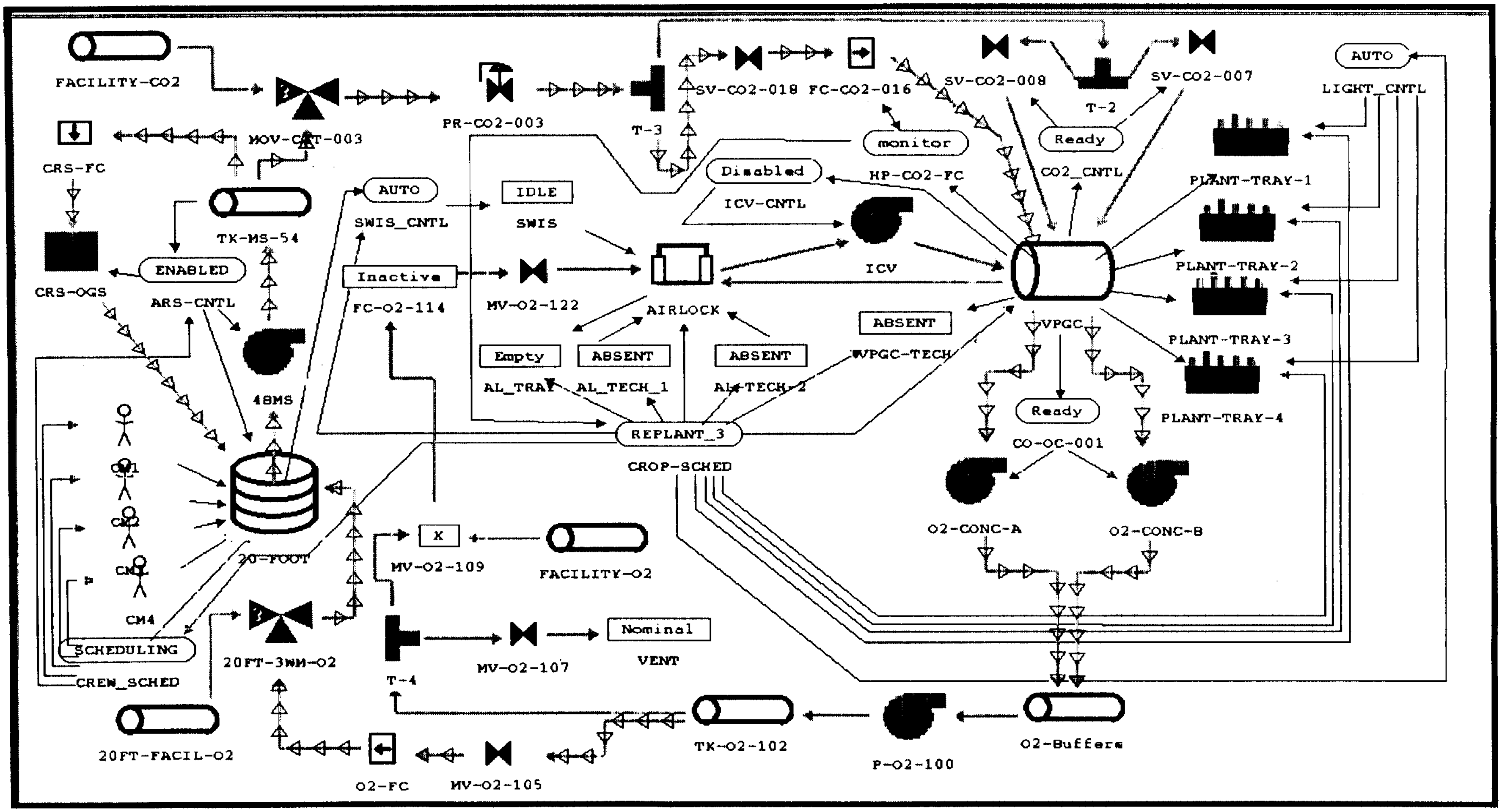
The project is a Phase II Small Business Innovation Research (SBIR) being conducted by Stottler Henke Associates, Inc. Its objective is to develop a suite of tools that can be used to create onboard health maintenance systems configured to handle problems in a variety of ALS systems. The tools provide knowledge editors that enable acquisition and representation of structural and behavioral models, descriptions of previously encountered anomaly cases, and descriptions of the operations and procedures that can be employed to obtain diagnostic information and to effect repairs. The tool suite also includes reasoning engines that synergistically combine Model-Based Reasoning and Case-Based Reasoning to perform fault diagnosis, and that employ Knowledge-Based Planning to generate recovery/repair plans. Finally, the tool suite includes a Crew Interface that can guide crew members step-by-step through execution of the generated procedures, employing multimedia presentations as communication aids.

The current work is focussed on the deliberative health maintenance tasks of diagnosis and recovery/repair planning. Future enhancements will add capabilities to perform the reactive sub-tasks of our health maintenance architecture: monitoring, fault detection, fault isolation and initial response generation.

Benefits and Uses

The onboard health maintenance system enables diagnostic information gathering and repair operations to be carried out by an intelligent crew member who has no special knowledge of the life support systems, because the health maintenance system contains all the necessary information and expertise. The system will improve crew self-reliance and autonomy from ground support, thus significantly reducing mission operations costs. With further development, the technology can be applied in many industries where the physical plant is complex, under-instrumented, and faults can involve hazards for personnel.

For further technical information, contact Jane T. Malin at (281) 483-2046 or jane.t.malin1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.



CONFIG Model: Advanced Life Support System in Phase III Lunar-Mars Life Support Test

SOF-7 CONFIG Modeling and Simulation Tool

Background

The automation of continuous and batch manufacturing of industrial products requires concurrent engineering supported by new hybrid approaches to simulation. Many manufacturing, power generation and communications systems have become highly automated. As process automation systems grow in complexity, a hybrid simulator is needed for analysis and evaluation of automated plant operations. A hybrid simulator is capable of modeling the heterogeneous discrete and continuous activities in the plant.

Project Overview

CONFIG, a hybrid modeling and simulation tool, supports design, analysis and validation testing of process automation systems. CONFIG can help you interactively test your software and procedures extensively before deployment in the real system, and to retest your hardware, procedures or software as they are changed during operations. CONFIG uses discrete event simulation technology enhanced with capabilities for continuous system modeling. Capabilities for continuous modeling include continuous integration algorithms and qualitative simulation, based on fuzzy sets. You can develop or specialize object-oriented models of equipment and with nominal and failure modes, plant topology, and operations procedures and control. CONFIG supports modeling, simulation, and analysis of system behaviors that are affected by events that dynamically change the topology of the system, by providing efficient graph analysis methods to determine local effects of global changes in flows and pressures. Although discrete event simulation technology has typically been used for stochastic analysis, CONFIG simulations are typically deterministic, for analysis of operational scenarios.

CONFIG has been used to test intelligent control and monitoring software for oxygen and carbon dioxide transfer between chambers in the Phase III Lunar-Mars advanced life support test. The simulation models the crew, plants in the growth chamber, gas processing systems, flow configurations, operating modes, schedules, procedures, and controllers. We plan to further enhance the development environment and to further integrate with continuous hybrid simulation. We plan to enhance procedure modeling to support studies of operator error and coordination of automated and manual operations.

Benefits and Uses

CONFIG can be used to validate advanced process automation software that includes both continuous and discrete control, with asynchronous interactive dynamic simulation. The technology can be used to analyze and predict effects of control actions and other events on the plant in various modes, whether local or global, immediate or delayed. It can also be used to analyze failure modes and effects and to analyze the capability of the instrumentation to support fault diagnosis.

Potential applications include analysis and design evaluation for industrial process automation for batch and continuous manufacturing, power generation systems and transmission networks, heating and ventilation systems and telecommunications systems.

This technology is patented and available for licensing. The current implementation runs on Unix operating systems. Cooperative agreements could support porting to Windows and Java.

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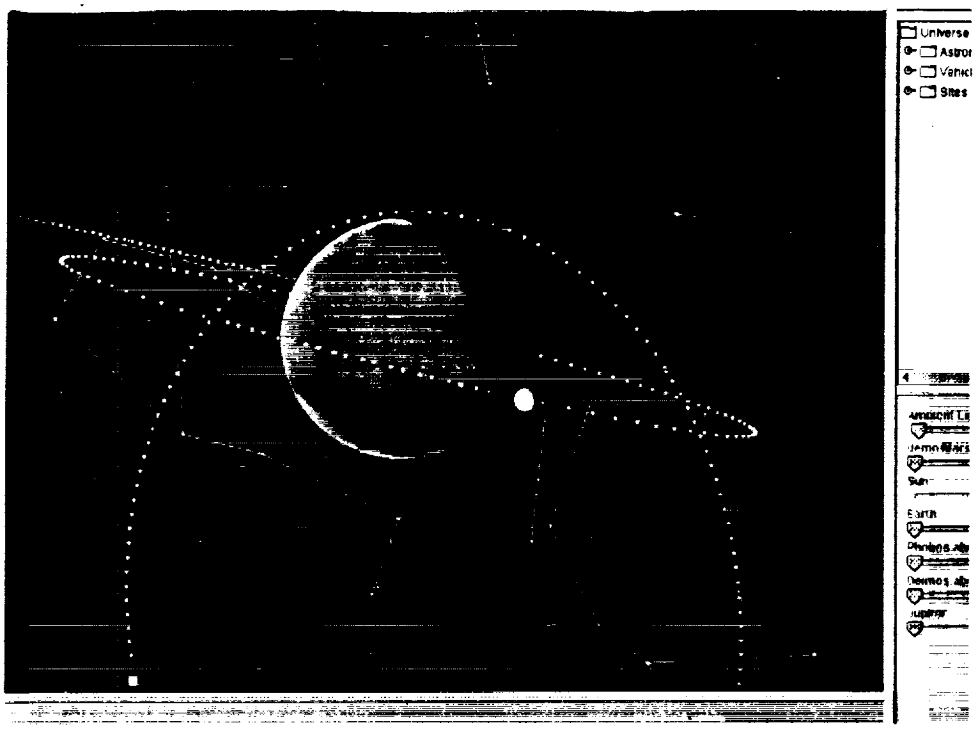
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.



PISCES output display illustrating lunar trajectory against celestial background.

SOF-8 PISCES – Platform Independent Software Components for the Exploration of Space

Background

PISCES is a software development effort to design a basic web-based architecture for orbital mission design and analysis. In 2000, PISCES will provide NASA with a multi-program rendezvous design and analysis capability capable of supporting missions around the Earth, Moon, Mars, and other planetary bodies. It will provide an enabling software library for future automated rendezvous techniques design and development as well as a software environment for evaluating ground versus onboard software partitioning.

Project Overview

We are re-tooling current trajectory design algorithms into a single object-oriented software library by using a collaborative effort between NASA and universities across the country, both to demonstrate alternatives to traditional contracts for this type of software development, and as a HEDS strategic initiative to *"form partnerships with educators to bring space exploration experience into the classroom... through implementation of new initiatives to inspire students to study science, mathematics, engineering, and technology"*.

In 1999, PISCES demonstrated the ability to perform precision trajectory propagation around the Earth, Moon, and Mars using complex gravitational models, atmospheric models, and the perturbative effects of solar radiation and N-body gravitation due to other planetary gravitations. Additionally, 3-dimensional interactive graphics was developed to allow the user to visualize these precise orbits using virtual-reality type of interaction. A generic framework for extendible software development was produced.

Benefits and Uses

NASA's current "trusted legacy code" for mission design is becoming difficult to maintain. Current applications, which consist mainly of Fortran and C codes, were written 25 years ago and are generally limited to low Earth orbit operations. These applications are difficult to understand, maintain, or enhance, and are not easily portable to new computer systems. This legacy code is unattractive to newly emerging college graduates, schooled in the object-oriented world and in a Windows environment, and limiting to NASA who needs maintainable and expandable capabilities. The future of NASA will depend on our ability to perform detailed mission design and rendezvous operations in orbits beyond LEO, and PISCES is positioned to become the singular tool of choice for rendezvous design and analysis for future NASA programs.

For further technical information, contact Don Pearson at (281) 483-8052 or don.j.pearson1@jsc.nasa.gov.
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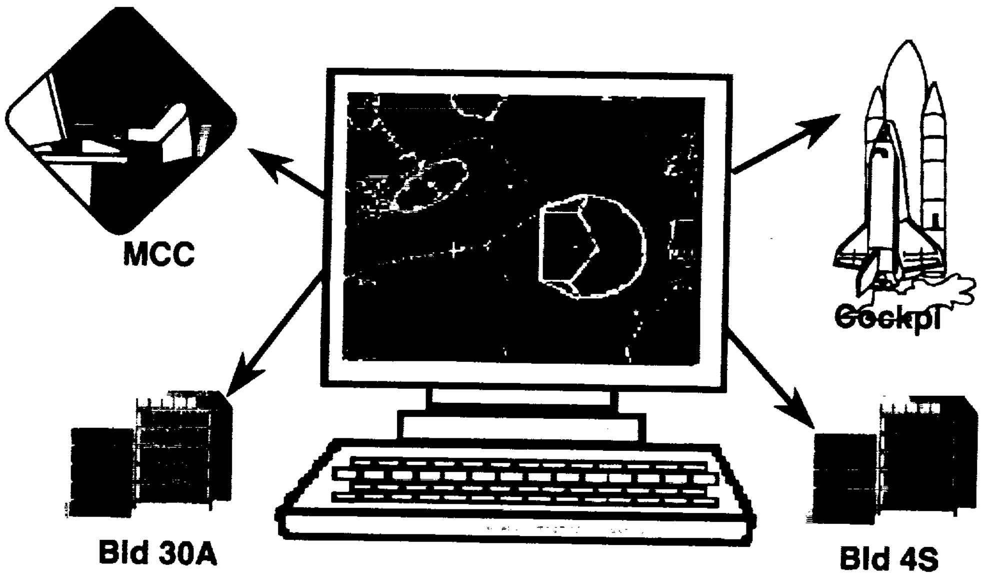

Platform independent ascent situational awareness tool for use in multiple facilities and computational environments.

SOF-9 Platform Independent Downrange Abort Evaluator (PIDAE)

Technology Category: Software

SOF-9 Platform Independent Downrange Abort Evaluator (PIDAE)

Background

The Downrange Abort Evaluator (DAE) currently exists in the Mission Control Center (MCC) mainframe Mission Operations Computer (MOC) and provides flight controllers with a real-time graphical situational awareness of landing capability for Transoceanic Abort Landing (TAL) aborts. Various assumptions are made regarding the number of Space Shuttle Main Engines running at the time of engine failures. External Tank impact locations are also displayed for range safety limit line avoidance evaluation.

This version shall be developed to be platform independent such that it could be deployable to a laptop computer on-board the Orbiter, as well as the MCC workstations and the various organizational trainers. This tool would greatly enhance the crew's situational awareness for emergency landing capability and proximity to range safety limit lines. Currently crew insight into these items is minimal or non-existent.

Project Overview

This project enables the development of a universal trajectory application that would support the needs of multiple users throughout the JSC community. This planned application would replace the prime MOC DAE application and output external tank footprint capability for Operational Sequence (OPS) 3 TAL, as well as OPS 6 East Coast Abort Landing/Bermuda aborts with enhancements to improve the fidelity of the footprint. The application will use a graphical user interface that requires minimal user interactions. Additionally, the application will be coded in the JAVA programming language for ease of portability.

By the end of 1999, the initial rehosting of the existing capability into JAVA and a preliminary driver for the OPS 6 display will be completed. In 2000 work will continue with additional graphics and a better program driving the OPS 6 DAE.

Benefits and Uses

The resulting application will be platform independent and readily portable to the various users and computer systems. Additionally, the final product will also reduce software sustaining costs since it would replace the multiple versions of the DAE currently being used across the Center (MOC, Crew Trainer, Flight Design & Dynamics Division Ascent/Entry Trainer, Flight Design, crew kneeboard PC version).

For further technical information, contact Christine M. Boykin at (281) 483-1251 or christine.m.boykin1@jsc.nasa.gov.
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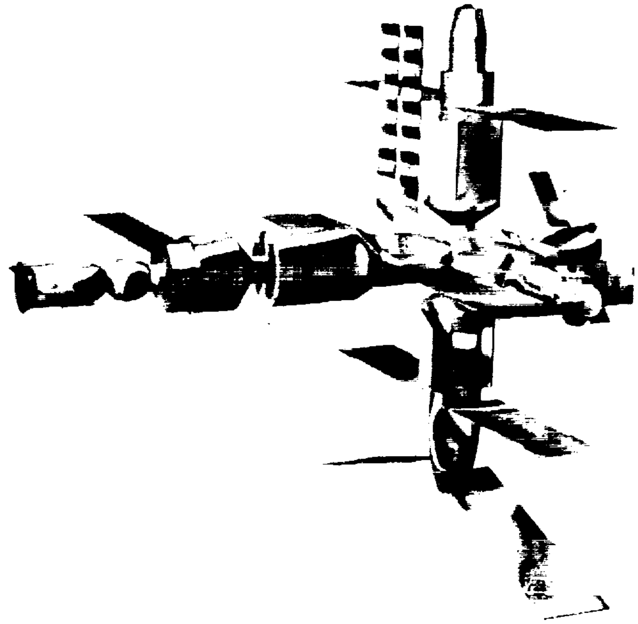
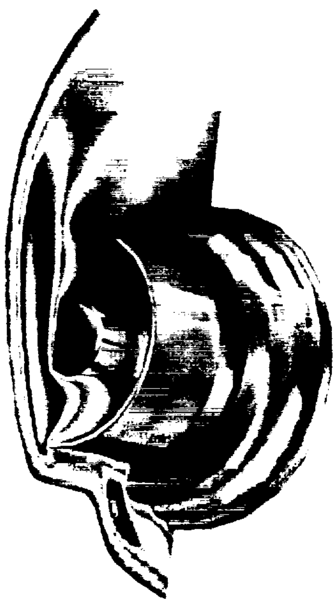
Low Earth orbiting satellites and space stations encounter small, albeit long duration, aerodynamic forces. The picture changes significantly when another spacecraft is in the vicinity and using its maneuvering thrusters. This was the case during the Shuttle-Mir missions, where the shuttle orbiter's thrusters could potentially damage delicate structural members. DSMC analysis was employed to validate engineering models used to design docking flight rules. The image shows the resultant pressure distribution on the Mir space station if the shuttle were to perform a Norm-Z burn (three jets pointing directly at the station) at a docking distance of 5 meters.





The DAC DSMC software has been employed by a number of corporate and educational organizations. This image was provided by a Department of Defense contractor that needed to investigate the surface heating environments of an optical sensor for a candidate exo-atmospheric missile defense system. Displayed are the surface heating rates on the optical tracking system and the flow field temperature profile as the vehicle flies at a slight angle-of-attack.

In 1997, Mars Global Surveyor began aerobraking into Mars' atmosphere, becoming the first mission to use aerobraking as a primary means of changing its orbit. Anomalies that occurred in the early orbits forced mission controllers to suspend aerobraking temporarily to protect the vehicle. These events presented a unique challenge to provide accurate aerothermodynamic predictions (pictured) for the spacecraft in the rarefied transitional flow regime. DSMC analysis played a critical role in understanding the anomalies and in formulating operational constraints for the safe resumption of aerobraking, allowing the vehicle to successfully complete the first phase of its mission.

Technology Category: Software

SOF-10 Direct Simulation Monte Carlo Analysis

Background

A computer code is being developed for the analysis of rarefied gas dynamic environments that cannot be properly modeled with more traditional computation fluid dynamics (CFD) approaches. The project has been a joint development effort between Johnson Space Center and Langley Research Center, with the goal of providing government and industrial organizations alike an effective means of simulating low density flows in lieu of costly testing. The software, named DAC, employs the Direct Simulation Monte-Carlo (DSMC) method of G. A. Bird, which is widely accepted as the preferred method for simulating rarefied flows. Although a number of DSMC packages have been developed over the years, they have typically maintained more of a research focus. As such, they lacked the requisite capabilities needed to handle the more challenging problems of today in high altitude aerodynamics, aerothermodynamics, satellite contamination, and reaction control system plumes analysis.

Project Overview

The development strategy for the DAC software involved combining the successful techniques of previous implementations with new and innovative features in a manner that automated as much of the process as possible. The DAC code employs a surface discretization technique with the necessary versatility to model the most complex geometric features, which can be created using widely available unstructured grid generation tools. Once the surface geometry is created by the user, the DAC software can automatically produce an appropriate flowfield discretization based on the requirements of the DSMC methodology. This approach spares the user from this inconvenient and time-consuming process, while also helping to insure that the simulation is properly formulated. The inclusion of state-of-the-art internal energy and relaxation process modeling and a variety of gas-surface interaction models and boundary condition options further contribute to the overall flexibility of the DAC software. The underlying power of the DAC software is its ability to utilize a single processor computer, a network of computers, or even the fastest parallel supercomputers, not only effectively, but also in an automated manner.

Benefits and Uses

The overall intent of this activity was to create a general-purpose implementation of the DSMC method that could be applied to a wide range of problems, while limiting the workload and requisite expertise of the end user. The enabling feature of DAC is its ability to apply literally hundreds of processors to a single problem, which has allowed the analysis of some of the largest, most complex, rarefied gas dynamic problems ever performed. Recent applications include space shuttle plume impingement on the International and Mir space stations, aerothermodynamic assessment of the Mars Global Surveyor performing an aerobraking maneuver at Mars, and aerothermodynamic heating to the optical sensor of a candidate exo-atmospheric missile defense system. In addition to traditional aerospace applications, the DSMC method has more recently been applied to problems in the semiconductor industry that take place in rarefied environments, such as plasma etching and chemical vapor deposition. The small scales involved in the emerging MEMS field may also warrant a rarefied characterization, thus requiring a DSMC analysis. Although development work continues in an effort to enhance the capabilities of the DAC software, it is available for distribution to interested parties under certain restrictions.

For further technical information, contact Gerald J. LeBeau at (281) 483-5208 or gerald.j.lebeau1@jsc.nasa.gov.
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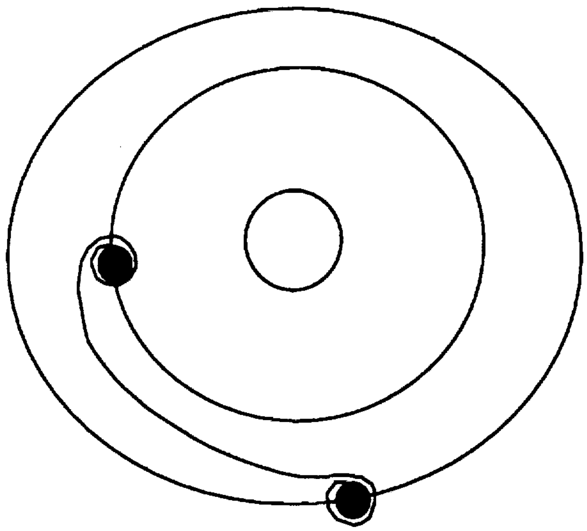

Example of Low Thrust Trajectory for Earth to Mars

SOF-11 Fuel Optimal Control Algorithm for Low Thrust Propulsion

Technology Category: Software

SOF-11 Fuel Optimal Control Algorithm for Low Thrust Propulsion

Background

While the idea of low thrust propulsion has been around since the early sixties, spacecraft using this technology for interplanetary missions may become a reality in the next decade. Low thrust vehicles use highly efficient electric thrusters to generate thrust that may be controlled by varying the specific impulse, ISP. The same low thrust vehicle is capable of either rapid manned missions with light payloads or longer duration unmanned missions with large payloads. Since the thrusting arcs are on the order of months, impulsive solutions cannot be used. Also, ISP limits must be imposed and gravitational influences of multiple planets must be included in the low thrust trajectory optimization.

Project Overview

This task developed a new control law and trajectory simulation that imposes the appropriate ISP limits and includes the gravitational effects of the relevant planets. The first problem addressed was to minimize the fuel for a fixed time Earth - Mars trajectory. The trajectory is divided into two phases: a) an Earth-centric phase that includes the Earth escape spiral and a portion of the heliocentric trajectory; and b) a Mars-centric phase that includes the rest of the heliocentric trajectory and a Mars capture spiral. The problem formulation treats the mass of the spacecraft as an explicit state variable, coupling the spacecraft and trajectory design. Using a fixed initial mass in low Earth orbit and transfer time, approximately 30 metric tons of additional payload was delivered to Mars as compared with previous methods. The next problem being addressed is minimizing the initial mass in low Earth orbit for a fixed transfer time and desired payload mass at Mars.

Benefits and Uses

This is a unique mission design tool that is being developed in partnership with Texas A&M University. This tool will enable the development of complete and accurate low thrust missions for near Earth operations and for exploration to other solar system bodies, using both variable and constant ISP. The tool is currently in the development stage.

For further technical information, contact Ellen Braden at (281) 483-8163 or ellen.m.braden1@jsc.nasa.gov.
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Visible human models used in the S3 project offer detailed anatomy with customized content, such as this color-coded muscle wall seen from inner and outer surfaces.

SOF-12 Somatic Sciences Simulation Project

Background

The Somatic Sciences Simulation (S3) Project enhances and expands NASA's use of virtual reality (VR) modeling, prototyping, and simulation to expedite a human-centered approach to future mission planning and operations. JSC has used VR technology to create remarkable training environments that replicate Shuttle mission experiments, Hubble Telescope servicing, and International Space Station modules. However, highly realistic and interactive VR models of the astronauts themselves, functioning within a virtual spacesuit during extra-vehicular activity (EVA), or undergoing the progressive bodily changes produced by the absence of gravity, have not been developed. The S3 Project focuses attention on the "human spacecraft", creating an alternative means of mission planning, on-orbit data analysis, and time- and cost-saving design and engineering for improved astronaut safety, mobility, comfort, and productivity.

Project Overview

Construction of the International Space Station will require more EVA in the next few years than all performed since the space program began. NASA also is forming mission plans for exploration of Mars and the Moon. There is a critical need for a virtual prototyping mechanism to 1) develop an advanced spacesuit and related support systems; upgrade and customize the EVA Mobility Unit currently in use; assess and implement effective countermeasures to microgravity; and enhance human factors analysis of mission training/performance.

The S3 Project is creating a high-resolution, interactive VR model of human anatomy and physiology, including anthropometric scaling, realistic motion and muscle action, a haptic (force feedback) interface, and an array of reference databases to support dynamic simulations of human tissues. Computer software and data capture/visualization technologies offer modeling of virtual equipment and environments, and integration with the customized parameters of the virtual human. Together they produce a simulation tool to evaluate and train for an array of mission-specific goals, conditions and variables.

Future developments include addition of the viscera (internal organs).

Benefits and Uses

The S3 Project is a virtual replica of the human body, which can conform to any shape or size, strength or limitation, attribute of health or disease. There are numerous examples of the dramatic time and cost savings realized through use of virtual prototyping of products in major US industries. Wherever there are "man-in-the loop" issues of human factors engineering; ergonomics; simulations of hazardous conditions, product design, fit or function; training scenarios; alternatives to animal research; market research; or custom manufacturing, there is now available a highly realistic and customizable VR human model. This virtual human (or humans) can be fully integrated into virtual environments and can actively interface with virtual products. The S3 Project technology has a patent pending and is available to be licensed for specific project applications.

For further technical information, contact Anthony Bruins at (281) 483-7071 or anthony.c.bruins1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

Dryden Flight Research Center EC99 45080-21 Photographed 09JUL1999
The X-38 Ship #2 following its release from the B-52 Mothership during the program's 4th successful preflight. NASA/Dryden Tony Landis

Technology Category: Software

SOF-13 Multi-Application ControlH (MACH) Flies X-38

Background

NASA's X-38 program is a series of test vehicles leading up to a Crew Return Vehicle (CRV) which will first serve as an International Space Station crew "lifeboat". X-38 test vehicles include subsonic vehicles dropped from the wing of a B-52 bomber and an orbital/entry test vehicle to be deployed by the Space Shuttle. Aggressive X-38 schedules call for efficient design of all systems, including the automatic flight control system (FCS). The classical FCS design approach is to tune point designs to meet performance and robustness requirements at selected flight conditions, then link these point designs together via gain scheduling, reiterating the process each time vehicle aerodynamics and mass properties change. The X-38 program is using Honeywell's Multi-Application ControlH (MACH) to reduce FCS design resource requirements for multiple test vehicles, as a single MACH design can fly the entire flight regime for multiple similar X-38 test vehicles with minimal modification.

Project Overview

MACH is a Honeywell implementation of a modern dynamic inversion control design technique. MACH dynamically inverts an onboard aircraft (OBAC) model of the flight test vehicle to cancel measured vehicle dynamics in real time and replace them with desired response characteristics in the roll, pitch and yaw axes. The dynamic inversion process may be thought of as real-time, model-based gain scheduling. Ideally, a single MACH design can fly throughout an X-38 test vehicle flight regime modeled by the OBAC and can fly other X-38 test vehicles with similar OBAC models inserted.

Whereas classical control design techniques often focus on one vehicle axis or single-input, single-output (SISO) feedback loop at a time, MACH can handle multiple input, multiple output (MIMO) systems and can optimize coupled aerodynamic flap control of multiple axes. This is especially useful for X-38 lifting-body test vehicles, which have highly coupled lateral-directional dynamics and strong rudder control authority in both the roll and yaw axes.

The X-38 project has used autocoding technology for generating C code from the MACH FCS design as well as the Shuttle-derived guidance and navigation designs. MACH source code was originally written in Honeywell's ControlH language, from which an autocoder generates C code for integration with guidance and navigation software and compilation in X-38 vehicle simulations and flight computers.

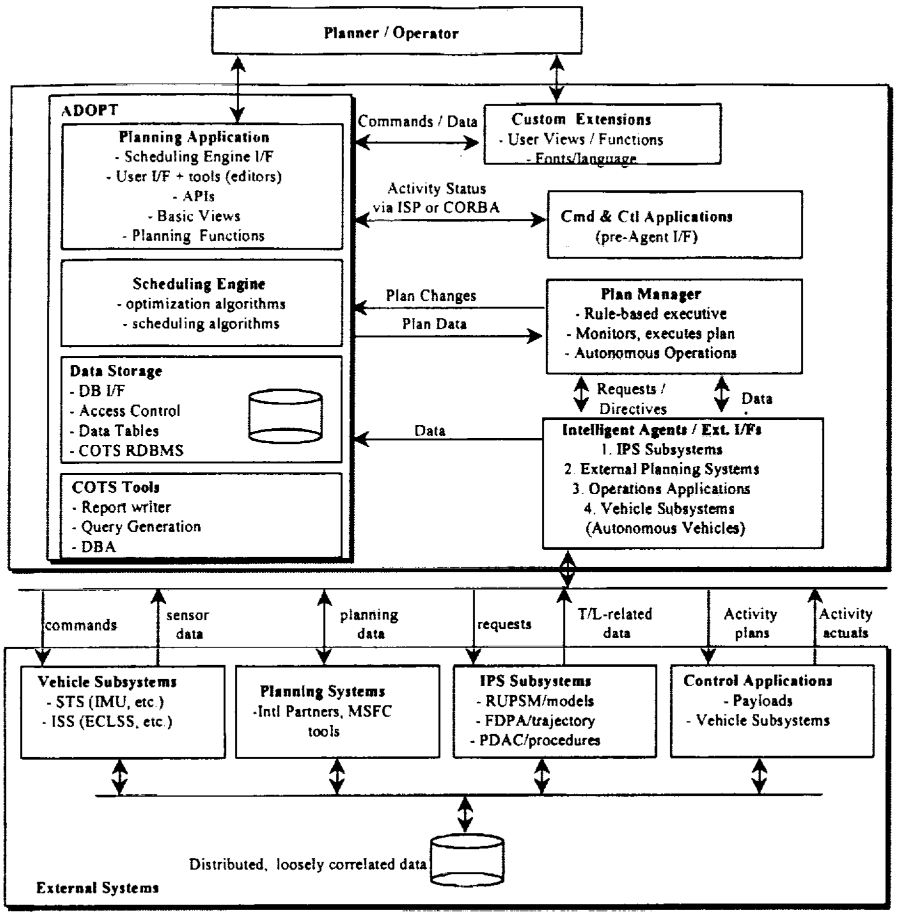
MACH flew the X-38 V-132 and V-131R subsonic test vehicles. Incorporation of RCS jet models into the OBAC will enable MACH to fly the V-201 orbital/entry test vehicle. Ultimately, MACH may be applied to the operational CRV as well.

Benefits and Uses

MACH reduces FCS design resource requirements by applying a single core design to an entire flight regime and even multiple similar vehicles. MIMO capability and optimal control allocation enables MACH to control a given number of vehicle axes with an equal or larger number of control effectors. Autocoding reduces the time required to convert a MACH design into flight code. MACH offers control designs for flight vehicles with highly nonlinear or coupled dynamics. Before X-38, MACH was applied in a High Angle-of-attack Research Vehicle (HARV) program, where aircraft aerodynamics became very nonlinear near stall points. Commercially, MACH can be applied to the automated flight control of a wide range of aircraft and spacecraft.

Questions regarding licensing and commercial application of MACH should be directed to Dale Enns and Dan Bugajski of the Honeywell Technology Center, enns_dale@htc.honeywell.com and danbug@htc.honeywell.com.
For further technical information, contact Stephen Munday at (281) 483-6623 or stephen.r.munday1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

Advanced Distributed Operations & Planning Technology



System diagram for ADOPT.

Technology Category: Software

SOF-14 Advanced Distributed Operations Planning Technology (ADOPT)

Background

Numerous fundamental questions arise from changes in mission planning and scheduling due to the increased flight manifest and the transition to distributed operations: Can planning and operations be better integrated through automation? How can data interchange between global planning systems be improved? How can planning work be spread across the office and mission environments more effectively? Can the architecture of the system be improved to reduce the cost of ownership? Can the planning system be generalized to be usable by other domains? The Advanced Distributed Operations Planning Technology (ADOPT) project was conceived to address the implementation feasibility of these questions. The project is a three-year effort with prototypes delivered at the end of each year.

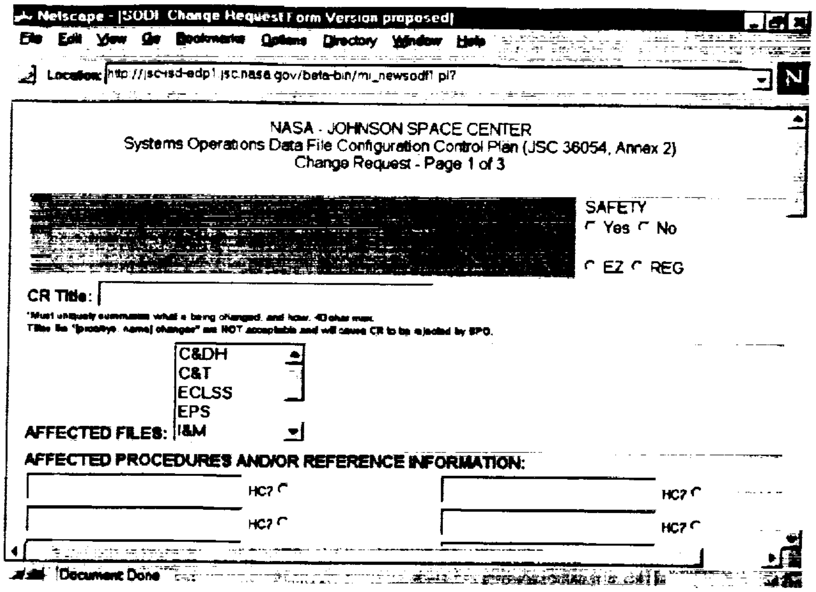
Project Overview

The ADOPT project was conceived to develop and evaluate, in partnership with other planning center developers, a prototype portable, scalable, mission planning system supporting automated planning, execution, and monitoring of ground, payload, and vehicle activities. Evaluation areas include: an extensible architecture with a standard internal data interchange mechanism, a server-based scheduling engine/database and support for multiple client applications supporting the office, ground (Mission Control Center), and on-board (Portable Computer System laptops and future autonomous vehicles) environments. The project also replaces obsolete commercial scheduling software with standard C++ library routines. The project has completed a prototype distributed architecture and has demonstrated a platform independent user interface.

Benefits and Uses

The principal usable product from this and our other efforts is an activity planning and scheduling system for a domain with resources that need to be shared to accomplish a set of well defined objectives. The system can be applied to any domain where resource limitations and constraints make it difficult to achieve optimum performance. The activities, constraints and resources are user definable and the system has a feature rich capability to produce a customized timeline of events. This technology can be licensed, but needs further development for commercial application. The developer, Lockheed-Martin, could support customization of the tools to other domains.

For further technical information, contact Mark Jernigan at (281) 483-9528 or j.m.jernigan1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.



Netscape - [SODF Change Request Form Version proposed]

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Location: http://jsc-sd-edp1.jsc.nasa.gov/beta-bin/mi_newsodf1.pl?

NASA - JOHNSON SPACE CENTER
Systems Operations Data File Configuration Control Plan (JSC 36054, Annex 2)
Change Request - Page 1 of 3

[redacted]

SAFETY
Yes No

EZ REG

CR Title:

*Must uniquely summarize what is being changed, and how. 40 char max.
Titles like "[prodtype, name] changes" are NOT acceptable and will cause CR to be rejected by SPO.

C&DH
C&T
ECLSS
EPS
AFFECTED FILES: I&M

AFFECTED PROCEDURES AND/OR REFERENCE INFORMATION:

HC? HC?

HC? HC?

Document Done

Technology Category: Software

SOF-15 Workflow – High Volume Data Management (HVDM)

Background

The concept of the High Volume Data Management (HVDM) project is to develop a web-based workflow system for increasing the efficiency and reducing the costs associated with process control and change management. As space operations become more distributed and both the volume and frequency of updates to the data increase, a paper-based change control process becomes ineffective.

To reduce costs and increase efficiency, electronic, automated processes are required to support the authoring, revising, reviewing, controlling, and releasing of changes to operations documents. Automated routing of the CR for approval and providing real-time electronic tracking of the status of each CR has eliminated the need for paper-copies of the CR.

Project Overview

The purpose of HVDM is to provide a web-based workflow system capable of automating any manual, paper-based process regardless of its complexity. HVDM provides a system of web-based, electronic forms that are submitted by users and automatically routed to the appropriate people for electronic review, revision, and approval. The HVDM system also provides real-time tracking, monitoring, and viewing of all change requests (CR) in the system so that the current status of a CR may be determined at any time. Process metrics may also be viewed to identify bottlenecks and allow for process improvement.

The HVDM project implemented workflow systems for two operationally significant processes: the Flight Rules Change Request for the Space Shuttle, and the System Operations Data File Change Request for the International Space Station. The Flight Rules and Operations Data File groups currently use the HVDM workflow systems to submit, review, approve, and control all change requests to their operational data books.

In addition to these operational systems, some prototype workflow development tools have also been developed, including prototype versions of a graphical process editor, a web-based electronic form designer, and a set of generic scripts used to perform the processing required at each step in the workflow process. Further development of these workflow development tools is required to expand their capabilities, simplify their interfaces, and integrate them into a cohesive workflow development tool set.

Benefits and Uses

Workflow automation directly saves reproduction and distribution costs in paper copies, as every part of the included process is now in an electronic format. It also significantly reduces the processing time for a CR, enhancing the overall organization productivity. The specific improvement is based on the complexity of the process being modeled, but in general it is approximately a 40% improvement in efficiency. Because the system is web-based, it supports distributed operations allowing users worldwide to participate in the change process, and it lowers training costs since people are already familiar with the use of web tools and applications. Further, it provides the information required for process management and improvement. The workflow system contains all the relevant information about any process, including the time spent for any process, or even any process step, based on operational data. This information enables the process owners to identify process bottlenecks and make decisions about how to streamline the process, or how to better use the available resources. This technology is currently licensed to Oak Grove Systems.

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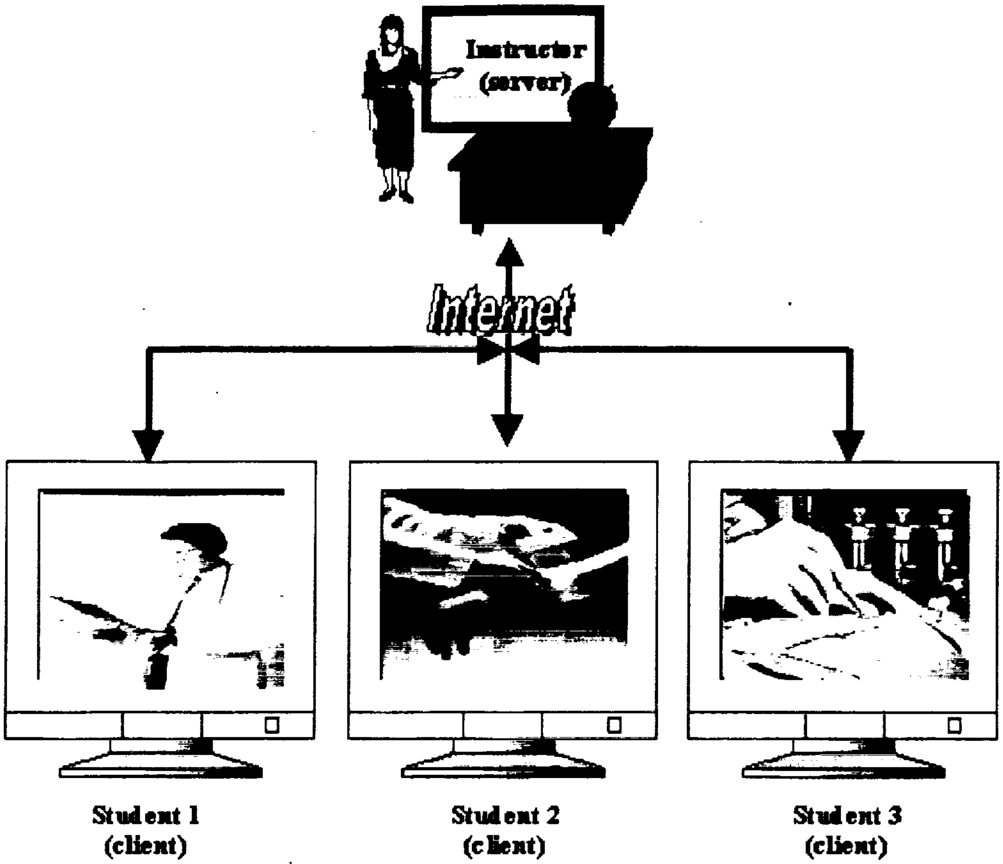
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.


Instructor
(server)
Internet
Student 1
(client)
Student 2
(client)
Student 3
(client)

SOF-16 Intelligent Collaborative Team Training

Background

The Intelligent Collaborative Team Training (ICTT) technology was developed to address the lack of a training architecture which supports the collaboration of a team of students training in a simulation-based environment from remote locations. This technology addresses methods for synchronizing student training simulations, coordinating which student should perform which actions, and storing both team and student model information. Prior research with Intelligent Computer Aided Training focused primarily on training a single student at a time. There was no proven technology that supported the remote training of a team of students. A move was made to pursue this approach to support distance learning for Shuttle/International Space Station crew in a flexible environment using either the Internet or LAN as the networking medium.

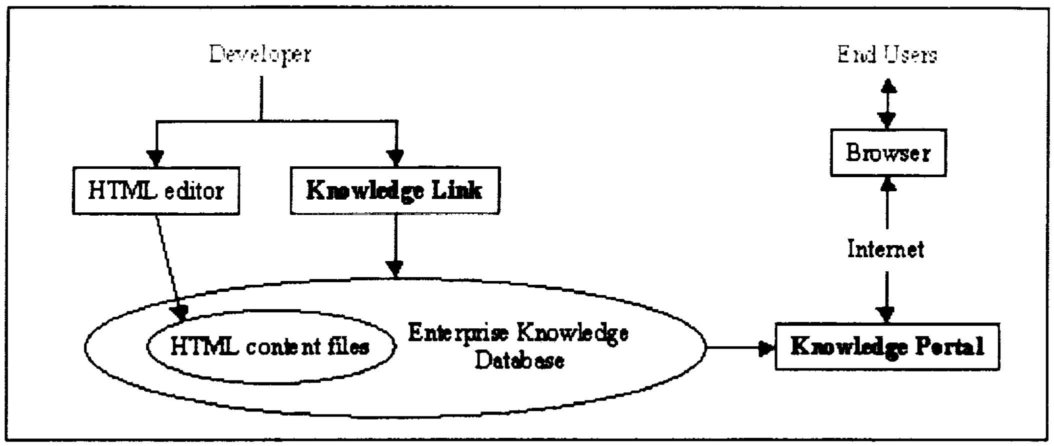
Project Overview

The objective of the ICTT program is to develop a software architecture, which could support the real-time, team training paradigm in areas which are too interactive and complex to be taught by workbooks or by classroom instruction. This ICTT technology serves to capture the knowledge of the subject matter experts and the best trainers to provide sophisticated, individualized training. Artificial intelligence technology is integrated with training and tutoring methodologies as a way of capturing scarce expertise and automating its use for training novices. The ICTT technology consists of a software library, written in JAVA and cross-platform compatible, and a set of knowledge capture tools, which aid in the creation of the domain expert portions of the training system. The library is then integrated with a simulation-based interface to provide training similar to what a human would provide but within a computer-based, instructor-less environment. The project has been completed and continues to be enhanced as required by various other NASA tasks. Work is currently underway to improve the capabilities of the tools to more fully support the capture of team training knowledge.

Benefits and Uses

The ICTT technology has many benefits including a generic training library which can be applied to various domains, reusability, cross-platform compatible, and robust training in an instructor-less environment. It also has many variations on how it can be applied – web-based training, desktop applications, embedded training, and virtual environments to name a few. The lessons developed using the ICTT tools also make maintenance very simple and cost effective since no coding is involved – unlike most other Intelligent Tutoring Systems (ITS). Many industries have training needs that could be addressed by team oriented ICTT simulations - medical, airlines, manufacturing, process control, utilities and the military. A very large potential target market for ICTT is in the training of "soft" people skills - such areas as emergency response coordination, how to work in teams, group decision making, etc. The ICTT technology is currently available for license although further maintenance is desirable to bring the software up to speed with the rapidly changing state-of-the-art Internet and Java technologies.

For further technical information, contact Robert T. Savely at (281) 483-8105 or robert.t.savely.1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.



Automatic Feedback Intelligent Trainer uses the Knowledge Link and Knowledge Portal to create custom training sessions for individual trainees.

Technology Category: Software

SOF-17 Automatic Feedback Intelligent Trainer

Background

This research addresses the general problem of producing high quality on-line (i.e., computer-based) training materials at a reasonable cost. The goal is the creation of a general-purpose software system for producing such materials called an Automatic Feedback Intelligent Trainer (AFIT). Previous research has shown that AFIT systems can be constructed, but their inputs must be presented in a specific, highly specialized format unfamiliar to the wide audience of professional trainers and educators. Thus the feasibility of this entire line of research rests on the development of an interface that bridges the gap between the input required by the underlying system and the natural expression of educational objectives familiar to professional trainers and educators.

Project Overview

The purpose of this research is to develop a practical and commercially viable AFIT training tool that can automatically create customized presentations and feedback for a trainee. The tool is divided into two subsystems, Knowledge Link and Knowledge Portal.

Professional trainers, termed developers, use the Knowledge Link subsystem in conjunction with any third party HTML editing tools to produce a knowledge database. This database is a general-purpose, format-free representation of the knowledge to be conveyed to trainees. Knowledge Link uses a point-and-click style interface useable by developers without any specialized background or training. The Knowledge Portal subsystem is a completely automated, server-based program that can read a knowledge database, format it, and present it to trainees (termed end users) over the internet or an intranet. Knowledge Portal keeps an internal model of each individual trainee, can present knowledge in a variety of different formats, and can customize knowledge presentation to meet specialized needs. Knowledge portal is a completely on-line application that can be run through any standard internet browser.

Knowledge Portal and Knowledge Link are currently being tested with commercial partners. Planned enhancements include adding XML compatibility, enriching the knowledge representation capabilities of Knowledge Link, and adding additional presentation formats to Knowledge Portal.

Benefits and Uses

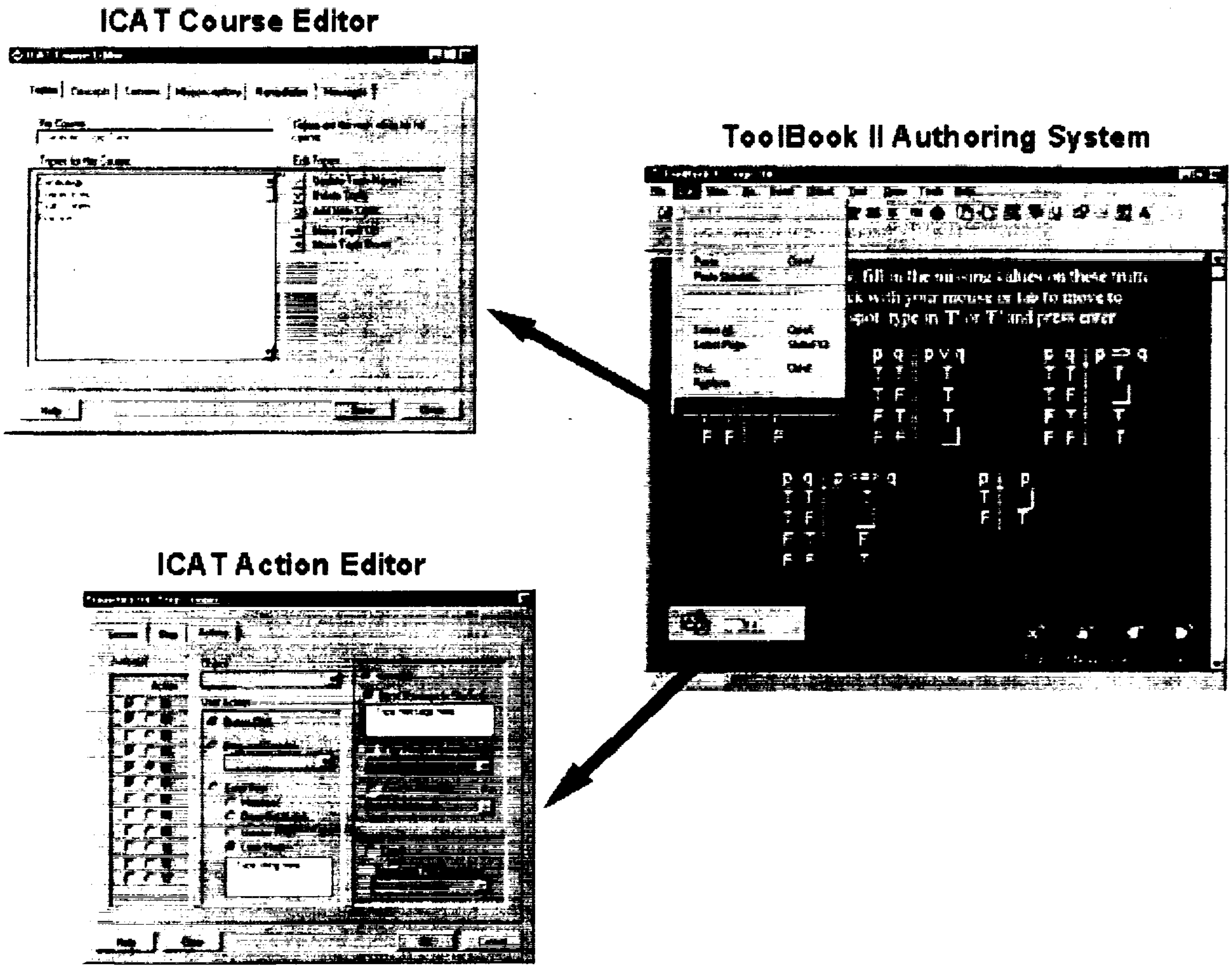
With the advent of the Internet, distribution costs associated with knowledge dissemination can be cut dramatically. The remaining bottleneck is the cost of developing knowledge content. This places the burden squarely on the shoulders of the developer, who must be able to develop high quality content in a form flexible enough to meet the demands of different end users in different settings. Knowledge Portal and Knowledge Link currently represent the only system available that permits developers to produce a single source of knowledge that is automatically presented in multiple formats (e.g., help systems, tutorials, customer support systems) that are customized to individual end-user needs.

A wide variety of potential applications exist for this technology, due to the continuous need for high-quality training that affects both government and industry. Specific potential applications include the construction of a general-purpose tool for constructing automatic certification programs, interactive software training applications, prerequisite training courses, self-paced education courses, and continuing education applications for professionals.

A patent has been filed for this technology that is currently pending. Future plans call for the technology to be licensable as soon as initial commercial testing is complete.

For further technical information, contact Robert T. Savely at (281) 483-8105 or robert.t.savely.1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.l.pido1@jsc.nasa.gov.

ICAT Enhanced Multimedia-Based Training



Technology Category: Software

SOF-18 ICAT Enhanced Multimedia-Based Training

Background

Traditional Computer-Based Training (CBT) developed with current commercial authoring systems, such as Authorware and ToolBook, can provide very powerful interactive multimedia presentations for teaching and training students. However, traditional course designers and developers are not taking full advantage of these interactive capabilities to produce new training approaches. There had been some interest in "intelligent navigation branching" in the past, but the resulting approach was a rather clumsy analysis of a user's pre-test performance that built a navigation path based on a series of questions. On the other hand, the Intelligent Computer-Aided Training (ICAT) technology previously developed for high fidelity flight simulations in the Shuttle Program has its strength in intelligent behaviors, such as student modeling and adaptive navigation and feedback. By combining the intelligent aspects of ICAT and the powerful interactive multimedia capabilities of CBT, current CBT courseware can become more challenging and effective in training critical skill areas in the Shuttle and Space Station Programs.

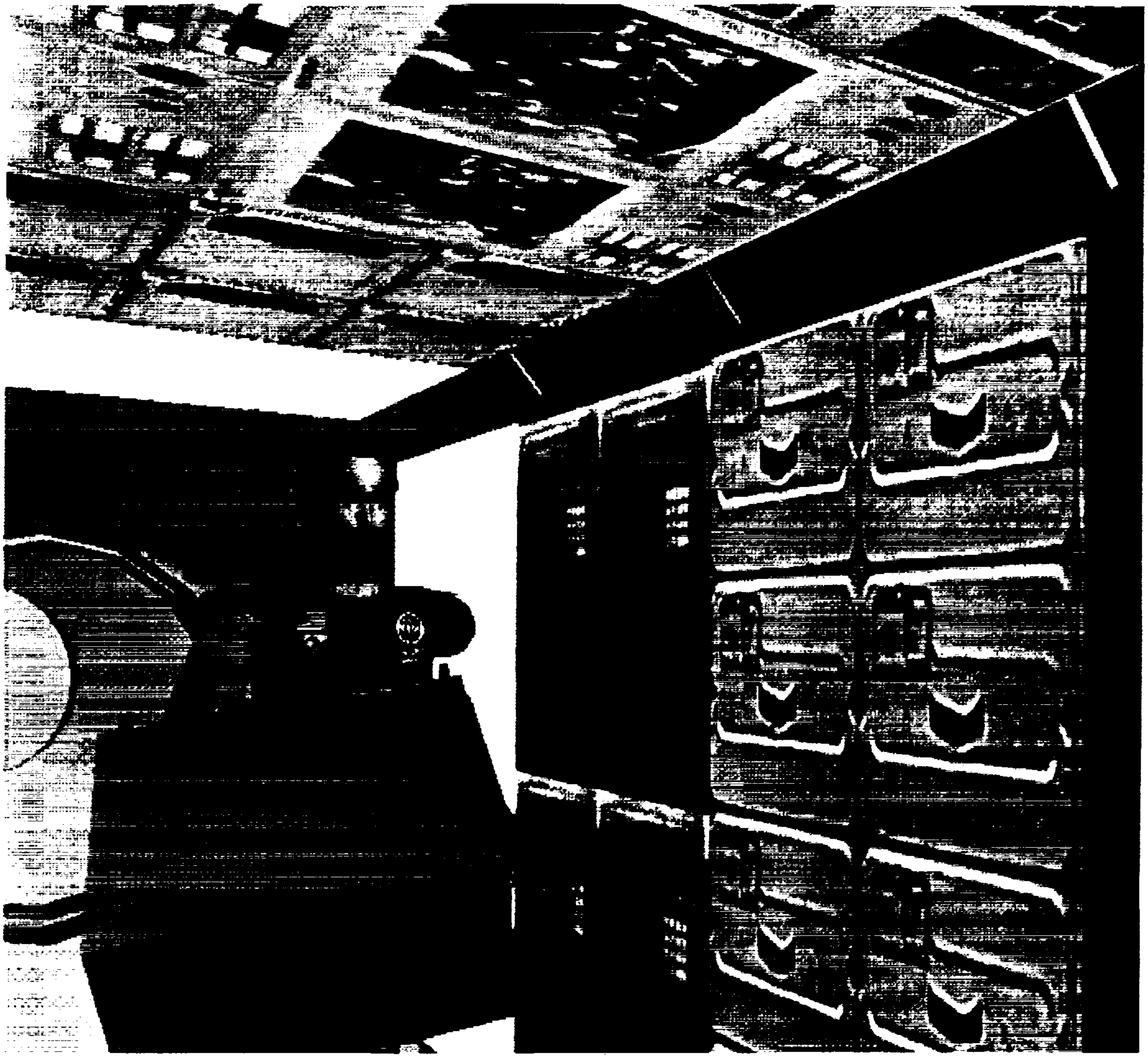
Project Overview

The objective of the ICAT Enhanced Multimedia-Based Training project is to develop a plug-in software that incorporates ICAT technology in Asymetrix's ToolBook II authoring systems. The plug-in has two modes, namely author mode and reader (runtime) mode. In author mode, the plug-in provides editing tools for course developers to layout the course structure and to capture expert knowledge, all within the ToolBook environment which developers use to create training contents. In runtime mode, the plug-in utilizes ActiveX technology to allow the ICAT runtime library to track and evaluate student interactions, to provide adaptive feedback and to navigate through course material dynamically. ToolBook's OpenScript scripting language is being used extensively to implement ICAT functionality in ToolBook. This project is in its first year of a two-year Phase II Small Business Innovation Research contract. An ActiveX component has been implemented for the ICAT runtime library. Editing tools and ToolBook templates are being developed next for the author mode. Student reporting capability and a prototype application will be developed in the second year.

Benefits and Uses

The ICAT plug-in for multimedia-based authoring systems adds intelligent navigation and adaptive feedback to traditional CBT courseware without requiring course developers to learn software programming. By distributing, installing and setting up a few extra files, ICAT technology is rapidly embedded in CBT applications. Potential users include courseware developers from industry, government, education or in CBT consulting. The immediate plug-in software will be developed for integration into ToolBook II authoring products and deployed via CD-ROM, DVD and LAN. It will be distributed as a shrink-wrapped commercial product at the end of the project. A follow-on product for Macromedia authoring systems and Internet and Web-based delivery methods will be created afterwards to assure the broadest possible commercial application.

For further technical information, contact Robert T. Savely at (281) 483-8105 or robert.t.savely.1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.



Technology Category: Software

SOF-19 Shared Virtual Environment for Team Training

Background

Many Space Shuttle flights include an astronaut from a foreign country. These astronauts usually carry out most of their training at the Johnson Space Center in Houston or in special facilities at other NASA centers. Thus, the support of international crews for the Space Shuttle has been at great cost to the nation from which the astronaut comes and has had a high personal cost for both the astronaut and his or her family.

This problem will only become more pronounced as training for the operation of the International Space Station (ISS) is added to that for the Space Shuttle Program. In order to reduce the costs of such training and remove the issue of where training should occur, the NASA training community has sought means of training teams of astronauts, at least to some extent, while each astronaut remains in his or her home country. The Shared Virtual Environment for Team Training (SVETT) project is the Johnson Space Center's principal effort to address the preparation of international teams of astronauts and ground-support personnel.

Project Overview

Based on the success of experiments conducted between Houston and Germany using the Hubble Space Telescope maintenance mission as context, a more refined testbed has been developed around the International Space Station (ISS). The training focus of this testbed is the conduct of scientific experiments and the execution of repair and maintenance operations within the ISS. Models of the interiors of selected ISS modules have been created and populated with highly detailed interactive models of the elements for which training has been developed and detailed but non-interactive models of the remaining interior elements. Trainees, equipped with a small number (usually four) of tracking devices, control human representations (known as avatars). Thus, the trainees can "see" each other as they carry out their tasks and can communicate non-verbally as well as verbally.

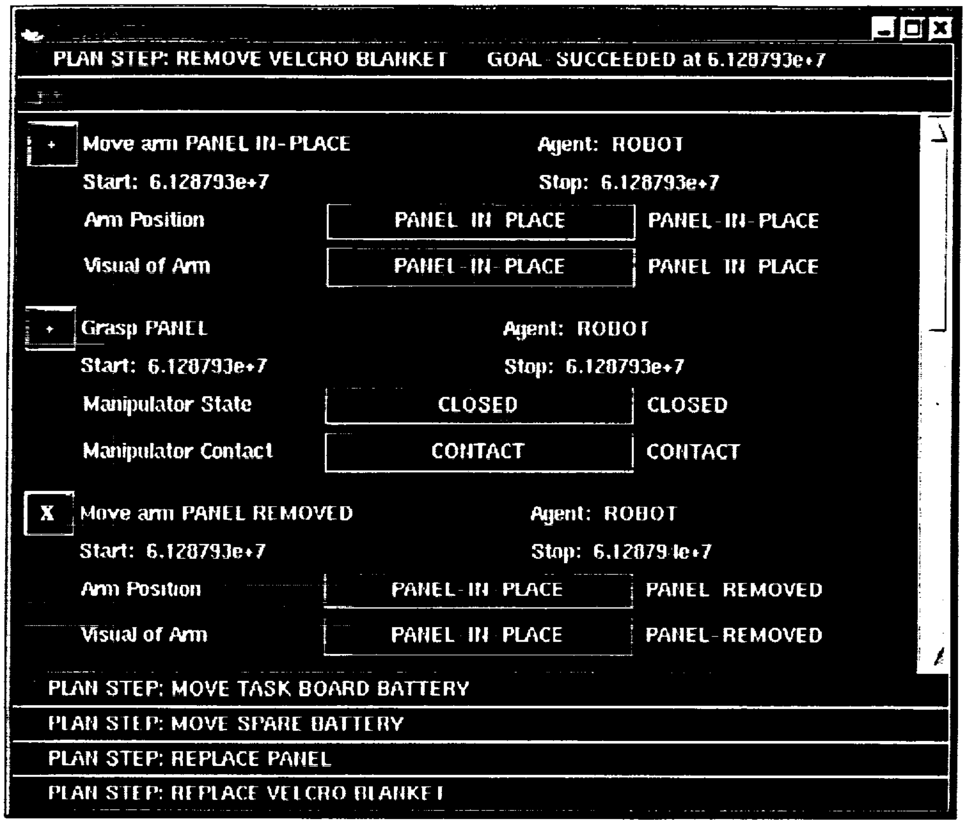
Any number of sites can be connected via a variety of communication network technologies, enabling team training to be delivered when and where it is needed. Integrated training for certain tasks of the international ISS crews can now take place while the individual crew members remain in their home countries; thus removing the complication of coordinating training schedules with travel plans.

Benefits and Uses

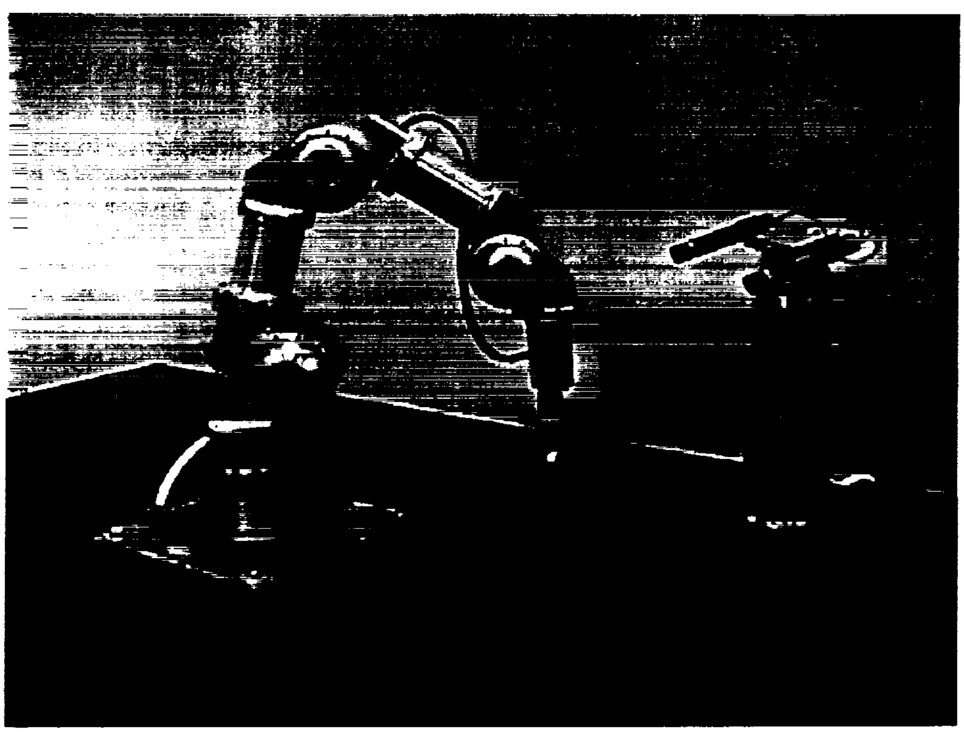
Shared virtual environments offer a number of uses for NASA, other government agencies, education, medicine, and the private sector. The benefits of shared virtual environments include reduced costs and time for collaborative design, decision making, mission planning, team training, telemedicine, and distance learning. Shared virtual environments may also reduce travel requirements for bringing participants to a single location for training, and will increase the efficient utilization of facilities and resources.

For further technical information, contact Robert T. Savely at (281) 483-8105 or robert.t.savely.1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

Graphical Users Interface (Fig 1)



Robotic Manipulator and Vision System (Fig 2)



JSC Research & Technology Report 1998-1999

Technology Category: Software

SOF-20 Intelligent Robotic Systems

Background

This research addresses approaches for integration of human and robotic tasks to complete activities required in human space exploration that neither human nor robot alone could perform or that neither alone could perform efficiently. Previous approaches have been constrained to tasks that could be performed manually by humans or to tasks performed by robotic systems that were teleoperated, which required the undivided attention of the human operator. Intelligent robotic systems are able at varying levels of functionality to determine current situation and to carry out the required task or goal-directed response to the situation. The approach of this research enables the use of intelligent robotic systems to augment human capabilities and allows the human to support the robotic systems with the human's unique cognitive and other skills when required.

Project Overview

The purpose of this research was to adapt a state-of-the-art architecture for autonomous control of an intelligent robotic system to provide integrated human interaction with the system and to demonstrate the feasibility of the approach. The architecture chosen for adaptation, called the 3-T architecture, has been successfully used for a number of research applications at the Johnson Space Center involving mobile robots, robotic manipulators, and environmental systems for life support. The architecture supports classical Artificial Intelligence technology planning at the top level, sequencing of incremental tasks resulting from the planning at the middle level, and reactive interaction between robot and the environment at the lowest level. The adaptation to the architecture uses the planner at the top level to plan both the human and robot tasks based on respective capabilities. It provides an enhancement of the sequencing and monitoring capabilities to enable the system to record task progress when performed by the human, and it provides an user interface (Fig. 1) that allows the human to understand what the control system is doing and intervene if necessary.

A state-of-the-art stereo vision system and six-degree-of-freedom robotic manipulator (Fig 2) performing a space related system maintenance task has been used to develop and demonstrate the technology.

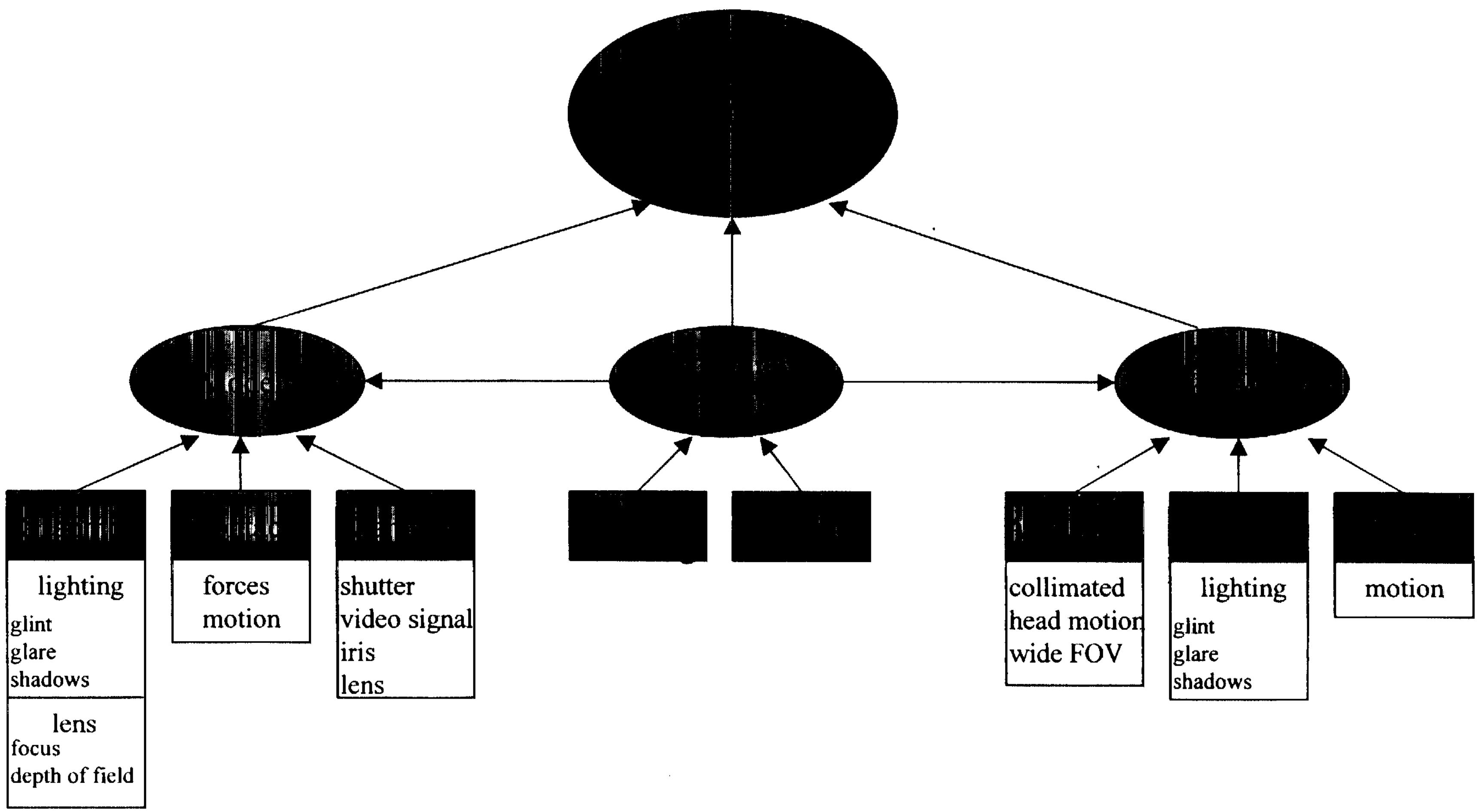
The system was recently delivered to the Johnson Space Center, Engineering Directorate, Automation, Robotics and Simulation Division's Intelligent System Branch where it is being used for research in the development of human-machine systems. The manipulator is to be mounted on a mobile base to provide further research and development opportunities.

Benefits and Uses

The benefit of the research is to allow a robot to work in an unstructured environment with human personnel. Such environments include space applications as well hazardous/nuclear waste clean up, the pharmaceutical industry, and food processing. The significance of this research is that it enables the use of intelligent robotic systems to augment human capabilities while enabling the human to support the robotic system with the human's unique cognitive and other skills where required. The technology is available for further development for commercial applications.

For further technical information, contact Thomas Pendleton at (281) 483--2039or pendleton@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.l.pido1@jsc.nasa.gov.

Alternative to Hardware Based Robotics Training (AHBRT)



Technology Category: Software

SOF-21 Alternativcs to Hardware Based Robotics Training (AHBRT)

Background

Since the start of the Shuttle program, training for robotics operations has included the use of both hardware and software based facilities. The hardware facilities are used because of the realistic visual cues they provide by having window views looking at real hardware and real camera systems. Operating the hardware systems also allows contact of hardware against hardware that produces cues to the operator for determining the position of a payload relative to the surrounding structure. The operator learns to use the subtle cues from the real world visual to develop situational awareness. It is the deficiencies in the ability to model the visual effects and physical contact that necessitates using hardware facilities for robotics operations training.

Project Overview

The Alternatives to Hardware Based Robotics Training (AHBRT) project goals are to develop and demonstrate software techniques and define technologies needed to simulate the hardware effects so that the software robotic simulators can be improved.

AHBRT will develop and demonstrate software models and techniques to simulate cameras and the visual effects displayed from real cameras. These camera models will control the visual effects and simulate the design of the camera and its effect on the scene that is rendered. The visual effects of physical contact of surfaces will also be simulated.

AHBRT will develop techniques for evaluating robotics simulators and will investigate systems for simulating out-the-window views as needed for robotics training. To maximize efficiency, the AHBRT project will also examine techniques to make these models transportable and reconfigurable so that they may be used in all robotic simulators used in training.

The project is currently starting its second year of a proposed three years. Accomplishments to date include the development of visual effect models that simulate various camera effects including glare, shadowing and blooming. Work has also been completed that will enable these models to be ported to simulators other than the development laboratory. An initial strategy for evaluating the simulators has been developed that will used for evaluating robotic simulators. A prototype collimated stereo display has been obtained and is being integrated into an existing robotics simulator for evaluation.

Benefits and Uses

Successful completion of the AHBRT project will lead to greatly improved simulation capability in the areas of camera and contact modeling that can be used in a variety of simulation environments. The project should identify technologies that can be applied to out-the-window scene generation that can be applied to many applications involving simulators that model window views and applications that require visualization of data. The evaluation techniques that are developed by AHBRT can be applied to other simulation environment to help determine which features are most effective in simulators.

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For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

The ROVer Ranch - Netscape

File Edit View Go Communicator Help

Rover Ranch

K-12 Experiments in Robotic Software

Register --- News --- Discussion --- Background

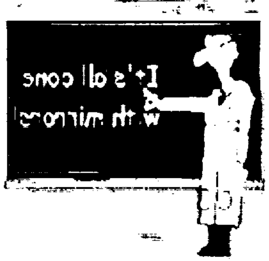
Saddle up!

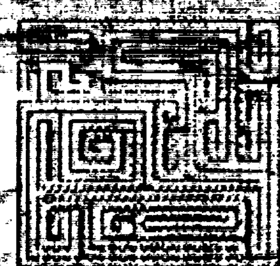
Sign up, and login podjo! Time to learn some fundamentals about robots and along the way, you can build, test and run a robot in a simulated environment.

The folks at NASA know a lot about robotic technology and want to share some of that information with you. This site contains activities, open-ended design opportunities and plenty to keep you wondering what could possibly be next in the world of robotics at the ROVer Ranch.

See you on the Ranch!

Mission Planning — Build a ROVer — ROVer Training — Special Missions





Technology Category: Software

SOF-22 ROVer Ranch

Background

The ROVer Ranch is a component of the Learning Technologies Project (LTP) which is NASA's leader for educational technology. The LTP supports NASA's Plan for Educational Excellence to research and develop products and services that facilitate the application of technology to enhance the educational process.

The ROVer Ranch is a technology-based robotics teaching tool based on NASA's mission that utilizes emerging software and network technologies. It complements other approaches to robotics education such as the FIRST Robotics Competition, Botball, and the Texas BEST Program.

Project Overview

The purpose of the ROVer Ranch is to foster complex learning and thinking skills within the framework of NASA's robotics mission. The ROVer Ranch is a Web site where students can build, test and run a software robot. Each student may select a mission and based upon the mission criteria, develop an appropriate robot to complete the mission. The first ROVer Ranch mission is based on an abstraction of the Sprint AirCam, a teleoperated robot used for remote inspection of the International Space Station (ISS). The display is a 3-D VRML model of the ISS driven by a Java simulation engine.

Students build their ROVer with components selected from a parts hierarchy organized according to function. Selections are motivated by mission requirements, environmental factors and general principles of robotic design. ROVers are tested by issuing commands or sequences of commands in a training environment. Once the bot passes basic training, the ROVer is moved to the proving grounds for its mission run. The proving grounds will contain uncertainties of the real world that may not necessarily appear in the training section.

The ROVer Ranch is currently under development with a beta release scheduled for the end of 1999. During 2000, two additional mission environments (exploration of a planetary surface and an underwater sample retrieval) will be added and these scenarios will require different aspects of mechanics, planning and critical thinking.

Benefits and Uses

ROVer Ranch benefits the educational community by providing an inquiry-based, technology-rich tool based on NASA missions. Users must engage in problem solving, data analysis, planning, and critical thinking exercises to accomplish a successful robotic mission. The underlying architecture of this software could also be used as a basis for modeling other industry sectors that require similar aspects of planning and critical thinking skills.

For further technical information, contact Dr. Robert Shelton at (281) 483-5901 or robert.o.shelton1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

The NASA Qwhiz - A Prime On-line Quiz Game - Netscape

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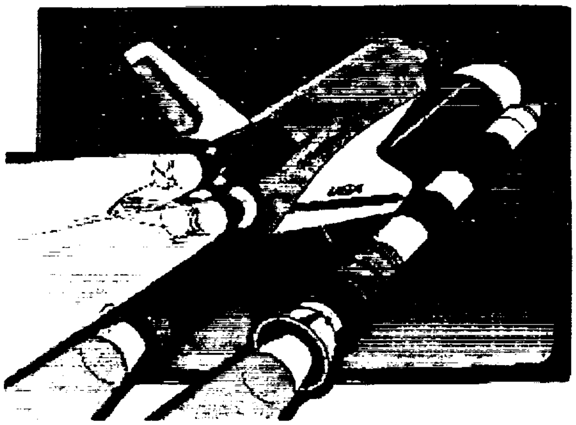


The NASA Qwhiz

\kwiz\ - Version 1.0

A Real-Time, Multi-Player, NASA Web Game

A K-12 Teaching Technology Tool

Qwhiz Tournaments

Scheduled Multi-Player Events

Qwhiz Library

Single-Player Games

Players

Sign up for a Multi-Player Qwhiz

Check the Qwhiz Calendar

The Qwhiz Hall of Fame

QwhizMakers

Open Registration

QwhizMaker Work Zone

Data Searches - QwhizMiner

er? Take a Qwhiz for fun! Learn about s

Technology Category: Software

SOF-23 NASA Qwhiz

Background

NASA has long been a contributor to American education: delivering instructional materials and services that spark interest and enhance learning experiences in science, engineering, and math. With the advent of the World Wide Web, and in keeping with national goals for science and technology education, NASA's Learning Technologies Project (LTP) has emphasized development of new and exciting technology-based educational products that are made available to the widest audience possible via the Internet.

Given the increasing demand for "NASA knowledge" and NASA's expanded efforts to make that knowledge widely available, a benefit to NASA and the education community will be derived from the availability of reusable tools which facilitate or otherwise enhance the process of developing and disseminating NASA-based educational products.

With these things in mind, LTP's Internet Tools for Teachers and Students component at the Johnson Space Center has developed a suite of tools for making and delivering multimedia science, math, or general subject quiz games and provided them via the web to educators, students, and the general public: NASA Qwhiz, Qwhiz Maker, and Qwhiz Miner.

Project Overview

NASA Qwhiz, Qwhiz Maker and Qwhiz Miner were developed to provide a fun way to share NASA knowledge with educators, students, or anyone who has access to the internet; therefore, the NASA Qwhiz suite of tools serves both formal and informal education.

The NASA Qwhiz educational software products provide for a way to take quiz games over the web in single or multi-player modes, allow users to make their own web-based quiz games, and provide support for content development of quizzes. Besides normal editing support (storage and retrieval of quizzes, editing abilities, etc), the tools also provide a customized search engine for finding content on the web, and then facilitate processing that data into the question and answer format.

The web-based, client-server technologies used to implement the NASA Qwhiz tools maximize ease of use. For example, the making and taking of quizzes involves simple interaction with the web site; there is nothing to download or install. The functional areas of the Qwhiz tools: interactive game design, editing support, personal work storage areas, content development support (search engine and data processing), process automation (product submission, review, and approval), and user interface design, manifest as single and multi-user client-server applications optimized to run in Netscape, and implemented using HTML, perl cgi, Java, and JavaScript.

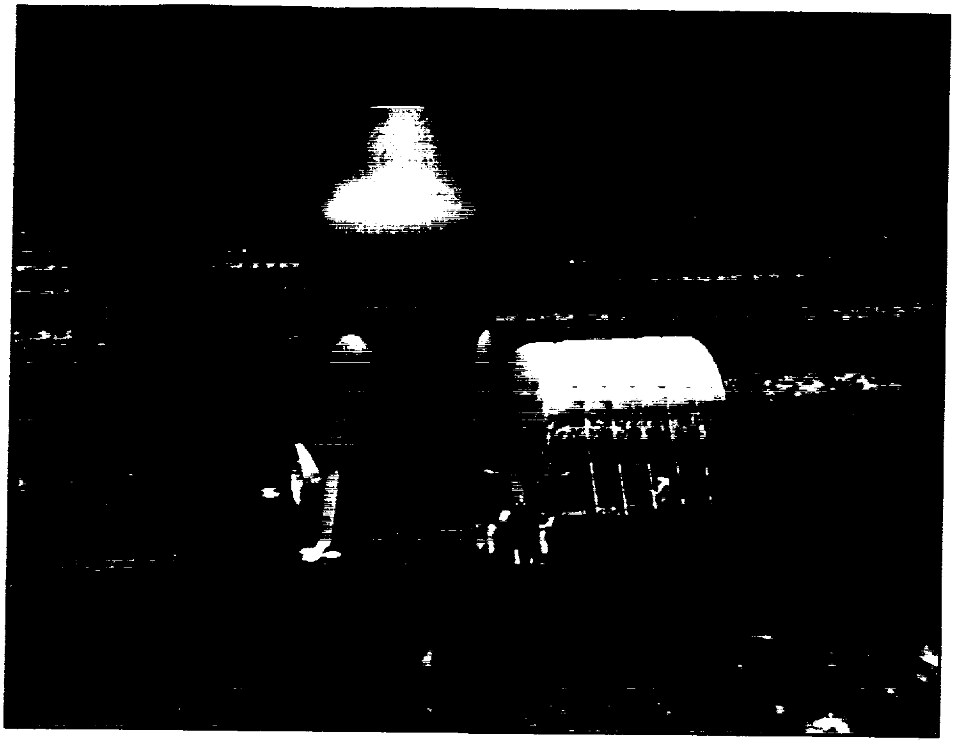
Benefits and Uses

NASA Qwhiz tools serve formal education in expanding standards-aligned technology and science content in the classroom, in easing teachers into the operation of computer applications, and in providing for and encouraging resource sharing of instructional materials via the Qwhiz Libraries.

Children and the informal education community benefit by having an entertaining way to expand their knowledge of the workings and benefits of science and engineering, and to gain experience with technology applications.

This product could easily be applied to web-based testing/training in industry - especially for distance learning/remote site learning. Product is available to general public for use via web site: http://prime.jsc.nasa.gov/Qwhiz/index.html.

For further technical information, contact Dr. Robert Shelton at (281) 483-5901 or robert.o.shelton1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.



Example of Crew Station on Mars

SOF-24 Reconfigurable Crew Station

Background

In preparing for exploration missions beyond low earth orbit, NASA is addressing the unique challenges of long duration and long distance operations. These factors influence the design of the vehicle's crew station, its command control (C&C) architecture, and the human-computer interface (HCI). The operations concepts (including the relationship between onboard and ground-based capabilities as well as crew and flight controllers interaction) are also influenced by these factors. In addition, there are many emerging technologies, such as advanced automation, that must be considered for future space vehicle operation.

In order to effectively and efficiently develop and refine crew station architectures and operations concepts, it is useful to have a visual representation of the crew station that can be rapidly reconfigured. The purpose of a Reconfigurable Crew Station (ReCS) facility is to provide this capability.

Project Overview

The Reconfigurable Crew Station (ReCS) project addresses the development of crew station architectures and operations concepts for exploration missions and upgrades to current vehicles. The focus of 1998 was on basic research, which included building a scenario-based report on concepts and architectures applicable to an exploration vehicle and mission. Virtual reality (VR) models were developed to illustrate basic command and control options. During 1999, the emphasis shifted to determining the capabilities and requirements for a ReCS facility. Facility construction will be preceded by a two-year capability demonstration phase in which existing facilities will be utilized and hardware/software will be purchased in order to demonstrate the key capabilities of the facility. This will have the added benefit of allowing some of the work that will be done in the ReCS to begin prior to facility completion.

In the ReCS facility, crew stations will be developed, modified, visualized, and utilized in a virtual environment that provides rapid prototyping capabilities. Software models will drive reconfigurable displays and advanced visual scenes. The crew station will contain sufficient hardware to support HCI and C&C concept development and implementation while maintaining a reconfigurable layout. This project will consider advanced technologies for virtual environments, intelligent automation, advanced crew interfaces, and other related areas.

Benefits and Uses

By developing a reconfigurable facility, crew station architectures can be visualized, worked with, and modified to incorporate new findings in a relatively low-cost facility compared to building high-fidelity hardware models and simulators for each potential configuration. The results can be fed back into the vehicle design process. The facility can also be used to develop and mature mission operations concepts through the execution of basic simulations.

This project uses existing technologies in a way that meets the unique needs of NASA, however, other industries that require rapid prototyping and visualization can utilize a similar approach. Some industries, such as automobile manufacturing, are currently using VR in the design and development process.

For further technical information, contact Susan E. Torney at (281) 483-2866 or susan.e.torney1@jsc.nasa.gov.
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SUBASSEMBLIES & COMPONENTS

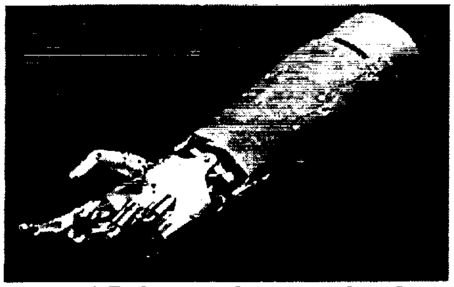


Figure 1 Robonaut dexterous hand

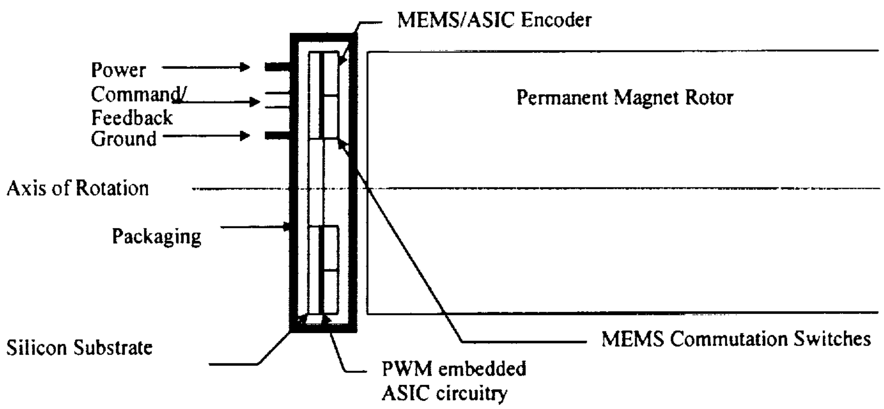


Figure 2. Schematic of the "Smart Chip". The device will be manufactured by producing an ASIC and then surface micromachining the necessary components for the encoder and commutation switches on top of that substrate.

SUB-1 Smart Motor Controller

Background

As a part of its technology demonstration, the Robonaut project is pushing the envelope in integrating electronics into a highly dexterous and compact robotic system. The state-of-the-art in mechatronic design is inadequate for a truly integrated system and requires the application of Micro Electro Mechanical System (MEMS) and Application Specific Integrated Circuit (ASIC) technologies to provide a robust integrated solution.

To expand on the innovative work being performed at JPL and JSC in ASIC and MEMS technology and its application to control of brushless DC motors, these technologies show much promise for increasing the level of integration achieved for future dexterous robotics. Without this technology development, human scale and smaller dexterous robotics will be unable to achieve fully embedded electronics, a minimum cable harness, and serviceable electronics and motor modules. Dexterous space robotics will otherwise be faced with the prospects of using existing bulky commercially available motor technologies, developing costly single purpose designs, or waiting for innovative new technologies to emerge elsewhere which can achieve further integration in mechatronic design.

Project Overview

The objectives of the Smart motor control Chip (Smart Chip) are to provide motor commutation, pulse width modulation control, velocity and current control, and position, velocity and current feedback in an integral package with the motor. The primary difference between the existing technology and the proposed technology development is the fabrication of ASIC and MEMS electronics that will make possible Smart Motors that are 1.5" in diameter and less.

The Smart Chip will integrate a radiation tolerant ASIC control chip, a MEMS encoder, and commutation stage on a silicon wafer die. In addition, the power stage will be integrated into the motor along with the smart chip to provide a fully functional motor. The integration of these fundamental components of motor control promises to provide intelligent actuators that perform signal and power processing integral to their electromechanical structure. This greatly reduces external components (thereby reducing the volumetric requirements) and simplifies interface to the motors.

In the first year of funding, the project has designed and fabricated a motor control ASIC and designed a MEMS encoder. Encoder fabrication and performance testing is planned for year two, with the third year focusing on integrated fabrication and environmental testing.

Benefits and Uses

This component technology can be applied to a wide range of aerospace and possible commercial uses. Any device that requires motor control in minimum packaging could make use of the products of this task. These applications include manipulator drives, sampling devices for planetary missions, instrument pointing devices, antenna tracking systems, interferometer translators for spectrometers and other systems. Classification of the technology would be "push" to the Robonaut program in particular and in general to dexterous robotics, sampling and rover programs. For example, the Mars 2001 program directed by Dr. Jake Matijevic has expressed interest in is use on his program. Dr. Patricia Beauchamp and Dr. Dave Rogers who lead the Center for In Situ Exploration and Sample Return Office at JPL expressed interest in its use in sampling systems for future robotic instruments and manipulators.

For further technical information, contact Scott Askew at (281) 483-8957 or scott.askew@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

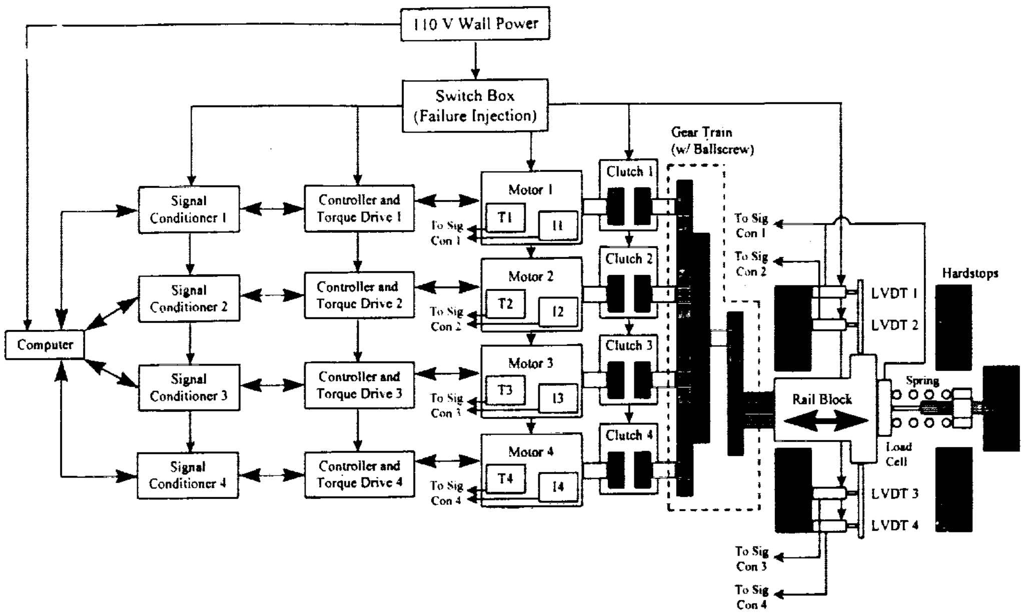


Figure 1: Schematic of EMA Test Bed

Figure 2: Photograph of EMA Test Bed configuration

Technology Category: Subassemblies & Components

SUB-2 EMA Test Bed

Background

Electromechanical actuators (EMAs) have been baselined for actuation of X-38/Crew Return Vehicle aerosurfaces and thrust vector control (TVC) of Lunar/Mars lander engines. They are also being considered for replacement of the hydraulic actuation system on the Space Shuttle Orbiter.

Although EMAs have been used in numerous aircraft and spacecraft mechanical systems, these devices have not typically appeared in high response, safety critical primary flight control system (FCS) applications requiring multi-string redundancy. Therefore, development and demonstration of various EMA architectures and redundancy management schemes must be performed to facilitate their use in primary FCS applications.

Project Overview

The EMA test bed is being used to develop in-house expertise in the design, testing, and operation of EMAs, thus mitigating risk associated with future primary flight control, TVC, or other safety critical multi-string applications. The primary objective of the project is to investigate hardware configurations and redundancy management schemes for optimal servo-control of a multi-string EMA system.

The test bed consists of a dual-fault tolerant EMA and an associated power and control system. The EMA includes four torque-summed brushless DC motors equipped with friction-type clutches driving a common gear train and ballscrew to produce a linear output. The power and control system includes motor controllers, torque drives, sensors, signal conditioners, power supplies, and a failure injection switch panel, plus a high-end PC equipped with LabView software for use in commanding, data acquisition, and critical fault detection, isolation, and recovery (FDIR) tasks.

At present, a full-scale checkout of the EMA test bed is underway. The initial FDIR algorithms have also been written and incorporated into LabView for testing (including failure injection). Additional FDIR algorithms and/or hardware configurations will also be tested.

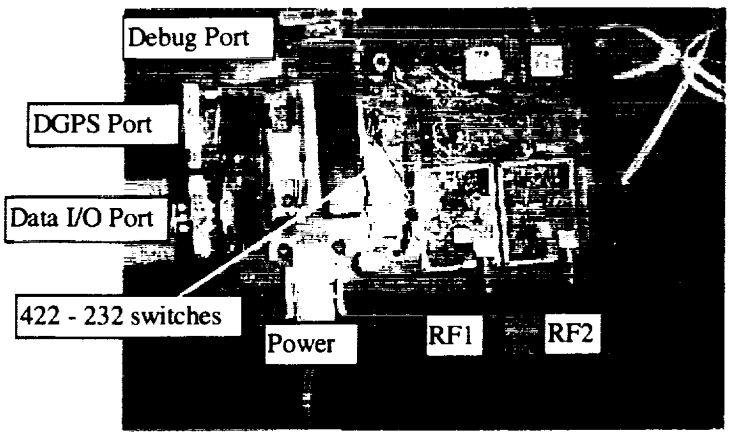
Benefits and Uses

The hardware configurations and redundancy management schemes evaluated in this project for optimal servo-control of a multi-string EMA have many potential uses within NASA, other government agencies, and private industry. In general, these concepts are applicable anywhere multiple electric motor drives are used for safety critical (multi-fault tolerant) positioning and control of an output.

Possible applications include process plant pumps and valves, aircraft aerosurfaces, elevator and escalator drives, construction and farm equipment actuators, and motion-based vehicle simulator actuators. However, the critical FDIR algorithms still need further refinement and exhaustive testing before being used for commercial applications.

For further technical information, contact John Albright at (281) 483-4246 or john.d.albright1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

TELECOMMUNICATIONS



Global Position System (GPS) 2 RF Front End Heading Board

Technology Category: Telecommunications

TEL-1 Global Positioning System for Heading and Position Determination

Background

The Port of Houston Authority and NASA have collaborated to produce a low cost Global Positioning System (GPS) based navigation system that will provide heading and position determination for ship channel traffic. Previous systems utilize a standard GPS receiver and provide only position determination, or high cost heading solutions that required an initial heading estimate.

Project Overview

The Houston Ship Channel Navigation System utilizes signals from the GPS satellites to calculate the position and heading of the ship. The information provided by the system gives the ship pilot an extra tool for safe passage through the Houston Ship Channel, even in marginal weather. System capabilities will eventually be expanded to provide radio broadcasts of current position and heading data to nearby ships to aid in collision avoidance.

The unit consists of a modified GPS receiver with 2 radio frequency (RF) ports and the custom heading determination software. The system has been built and tested at JSC, with field testing performed on two fireboats. The software was written and incorporated into the unit to compute heading with or without an initial heading estimate. Results show an accuracy of about 1 degree in heading, which met the Port's expectations.

Additional units have been built and software modifications are underway to operate in space at orbital velocities and to track pseudo GPS satellites. The unit could be expanded to produce outputs of roll, pitch, and heading.

Benefits and Uses

The unit's reproduction costs are much lower than comparable units on the market. It could be used by any vehicle or device that needs or desires position and heading information. The unit, if expanded, could provide 3 axis pointing information.

The drawings and software executable are currently available. This project has been disclosed as a new technology.

For further technical information, contact Susan F. Gomez at (281) 483 2021 or susan.f.gomez1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

TRANSPORTATION

Dryden Flight Research Center EC99 45080-21 Photographed 09JUL1999
The X-38 Ship #2 following its release from the B-52 Mothership during the program's 4th successful preflight. NASA/Dryden Tony Landis

Technology Category: Transportation

TRN-1 X-38: Prototype for Crew Return Vehicle

Background

The X-38 project is an in-house experimental spacecraft project that will demonstrate and develop the requirements for the Crew Return Vehicle (CRV) for the International Space Station (ISS). The project utilizes a rapid prototyping approach for development and testing of the technologies necessary for use in the CRV. The X-38 project consists of 3 atmospheric demonstrator vehicles and one spaceflight vehicle. The atmospheric demonstrators are single string vehicles that test the aerodynamic flight below MACH 1 of the lifting body vehicle and test the transition from lifting body flight to parafoil flight of the system. The spaceflight vehicle will be "CRV like" with full redundancy and a life support system that is capable of supporting human life. All X-38 tests will be performed in a crewless configuration.

After 12 previous studies for CRV concepts, this is the first project to develop hardware and produce flight test results. This is possible due to the rapid prototyping approach and advances in technology in the avionics and parachute fields that greatly reduce the cost and time required to develop and test these systems.

Project Overview

The X-38 utilizes a lifting body shape to provide cross range advantages over previously proposed ballistic shapes. Utilization of the lifting body ensures that the crew will have a minimum of 3 landing opportunities in any 9 hour period after departure from the ISS. In most cases the crew is on the ground in less than 2.5 hours.

Since the CRV has a requirement to be fully automated from ISS departure to landing, the X-38 will demonstrate this capability during the space test flight of the final X-38 vehicle. The spaceflight vehicle will be taken into space via the Space Shuttle and will be deployed by the shuttle's robot arm. The X-38 spaceflight vehicle will then fly automated from space to its designated landing site on earth.

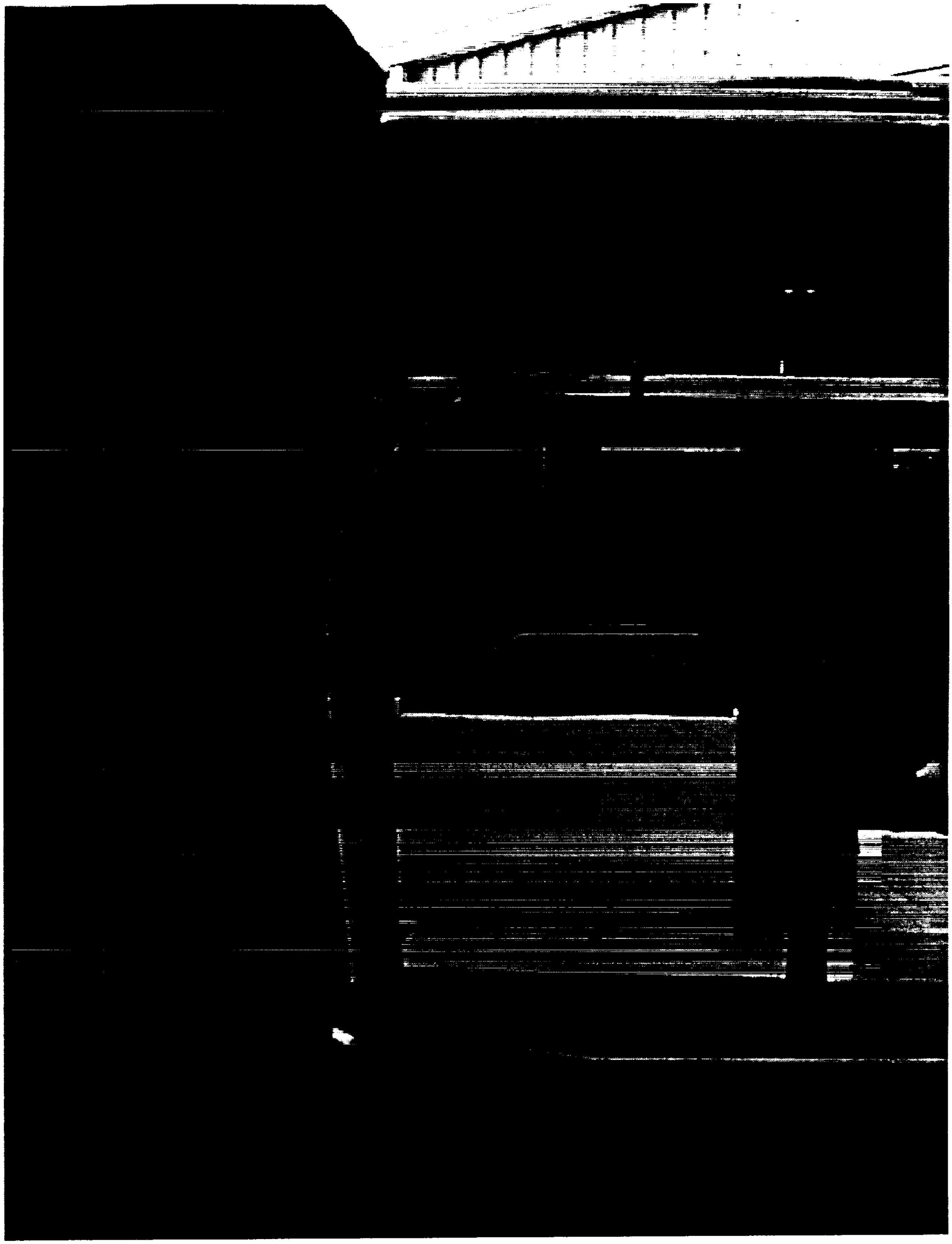
The vehicle utilizes COTS systems in many of the avionics and systems areas. The use of COTS greatly decreases the overall cost of the project and, in many cases, decreases the amount of time required to integrate and test the systems for use on the X-38 vehicles. The greatest areas of new technology are in the parafoil systems, electromechanical actuators, advanced thermal protection systems, and in use of Dynamic Inversion for the flight control system. The project utilizes many new technologies for software development and maintenance and has optimized the design and construction of the vehicle with advanced software and measurement tools.

The project is currently in the atmospheric test phase with two active atmospheric vehicles. The spaceflight vehicle is under development and the structure is almost complete.

Benefits and Uses

The primary benefit of the X-38 project will be the low cost development of the CRV for ISS. The X-38 has been developed with the cooperation of the European Space Agency (ESA). ESA has an interest in advancing the design as a Crew Transfer Vehicle that would be launched off an Ariane 5 expendable vehicle. The overall design of the X-38 will allow it to be modified for future vehicle considerations.

For further technical information, contact Brian Anderson at (281) 483-4436 or brian.l.anderson1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.



Technology Category: Transportation

TRN-2 Remote Cockpit Van: Integrated Handcontroller & Display Technology

Background

One of the major challenges discovered as part of the development of a new Crew Return Vehicle (CRV) for the International Space Station (ISS) is how to transition between crew member decision making and an autonomous operating vehicle. This interface must be capable of allowing a crew member to intervene and then seamlessly return control of the mission back to autonomous operations as required. Developing an optimal crew interface requires close coordination with potential operators and the ability to rapidly respond to crew input with changes to the operating system. Each new change to the interface must be evaluated in a realistic simulation providing a valid simulation of real world flight conditions.

Project Overview

The Remote Cockpit Van Integrated Handcontroller and Display Technology Project is designed to provide rapid prototyping of displays in an integrated environment, including a motion based simulation capability. A prototype cockpit installation is located in the back of a 15 passenger van, nicknamed the "Vomit Van" due to its similarity as a mobile test bed with the KC-135 "Vomit Comet."

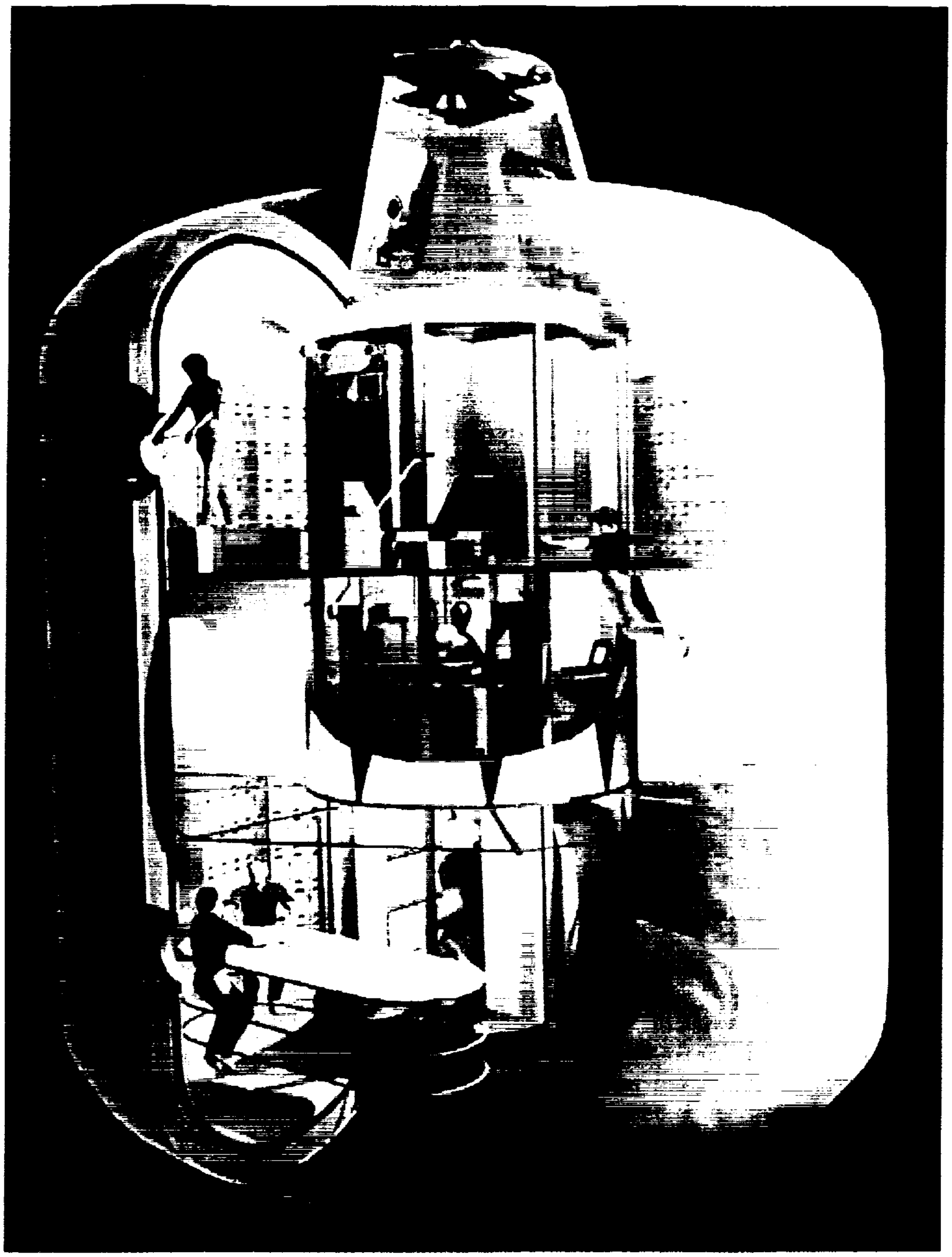
The combined system has three primary functions. First, the system provides a "Rapid Prototyping" cockpit testbed for display software development and display evaluations; digital terrain and video sensor fusion development; handcontroller evaluations; and external sensor display and control evaluations. The van also functions as a "Motion Base Simulator" for the parafoil and landing flight phases of the CRV. The van moves to simulate the forward motion of the CRV while the crew lies recumbant as they would in the actual CRV landing phase. Furthermore, the van incorporates a "Remote Cockpit" to actually allow a crewmember to control the flight of a vehicle during CRV flight test and development. As the actual crew flying the CRV from the ISS will probably be somewhat decapacitated from their extended time on-orbit, the controls in the CRV must take into account this limited crew capability and restrictions on motion due to their recumbant position.

The Remote Cockpit Van is a multi-directorate project, involving personnel from Engineering, the Astronaut Office, Mission Operations and the CRV program office.

Benefits and Uses

This study is expected to produce the optimization and incorporation of a display unit and an integrated handcontroller into various remote piloting activities, such as parafoil/vehicle guidance, navigation, and control, vehicle systems monitoring, display navigation and control, and communications. The work will help define requirements for the Crew Return Vehicle crew interface in addition to refining strategies for the optimal interface and control of a mostly autonomous vehicle. Additionally, since this platform supports rapid reconfiguration and display changes, future cockpit studies for advanced vehicles could be quickly and inexpensively performed with rapid responses to crew inputs. Both advanced commercial cockpits and the future manned Mars landers could benefit from this technology study.

For further technical information, contact Scott Altman at (281) 244-2228 or scott.d.altman1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.



JSC Research & Technology Report 1998-1999

Technology Category: Transportation

TRN-3 TransHab Inflatable Module

Background

The concept for the TransHab inflatable module originated at the Johnson Space Center in 1997 as a possible design for living quarters on future Mars-bound spacecraft. Engineers at the Johnson Space Center were challenged to find a way to develop a lighter, cheaper spacecraft for manned missions to Mars. The basic design and technology are appropriate for space and planetary surface habitats.

Project Overview

Rather than the standard aluminum shell used for most space structures, the TransHab incorporates a layered shell over inflatable air bladders as the primary structure. The outer shell is comprised of layers of Nextel spaced between layers of open cell foam. A layer of woven Kevlar holds the module's shape and triple redundant Combitherm air bladders provide the pressure shell. The innermost layer, forming the inside wall of the module, is fireproof nomex cloth that protects from scuffs and scratches. With almost two dozen layers, the foot-thick shell provides better debris protection and thermal insulation than metal.

The TransHab is under consideration for use as the habitation module for the International Space Station (ISS). It would provide a home for up to six astronauts on board the station, complete with bedrooms, a kitchen, a dining table that seats 12, two windows, a gym, a pantry, and storage space. The TransHab would provide more room (about three times the room) and weigh less per cubic foot than conventional metal modules.

In 1998, NASA successfully demonstrated the structural integrity of the fabric structure with a pressure test to 4 times the maximum operating pressure of the ISS (higher than any other space module). Additionally, a full-scale inflatable module was successfully built and demonstrated the packaging, deployment, inflation, and operating characteristics of the inflatable structure in a space simulation environment. TransHab also successfully demonstrated by test superior performance in elements such as radiation and orbital debris protection.

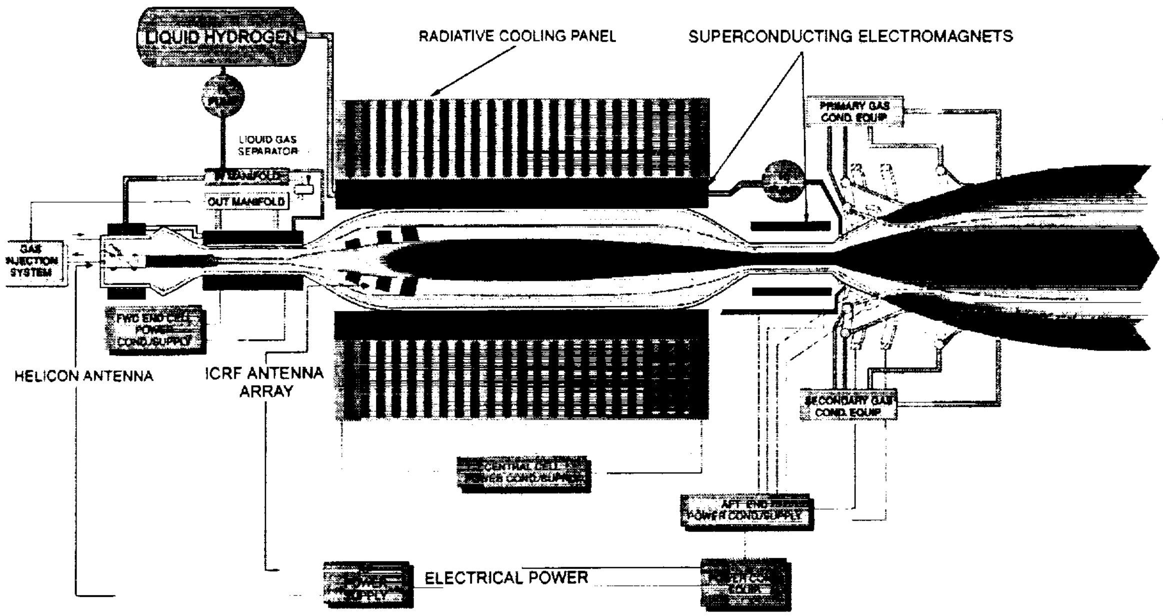
As the first inflatable spacecraft, TransHab could be a stepping stone to future space exploration. Inflatable spacecraft may have a great potential for use aboard a Mars-bound spaceship and as inflatable shelters on the Moon or Mars.

Benefits and Uses

This technology offers significantly reduced weight and manufacturing costs for highly loaded pressure vessels. The technology can be applied across industry sectors for various space and earth based applications. The technology is available for licensing and can be customized to suit the required application.

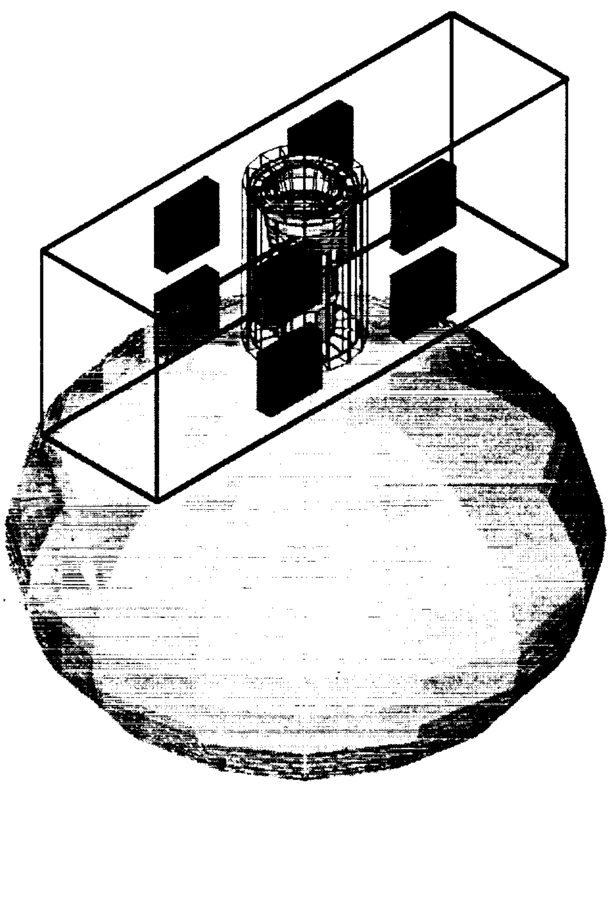
For further technical information, contact Horacio de la Fuente at (281)483-8842, horacio.m.delafuente1@jsc.nasa.gov.
For technology transfer assistance, contact Kelle Pido at (281) 483-1348 or kelle.i.pido1@jsc.nasa.gov.

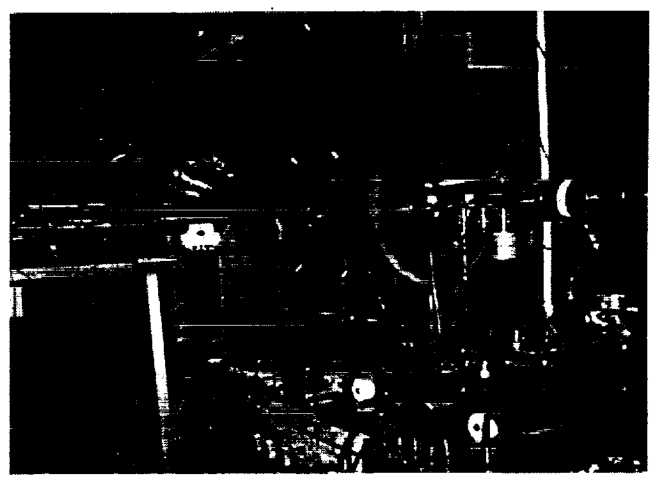
VASIMR Concept



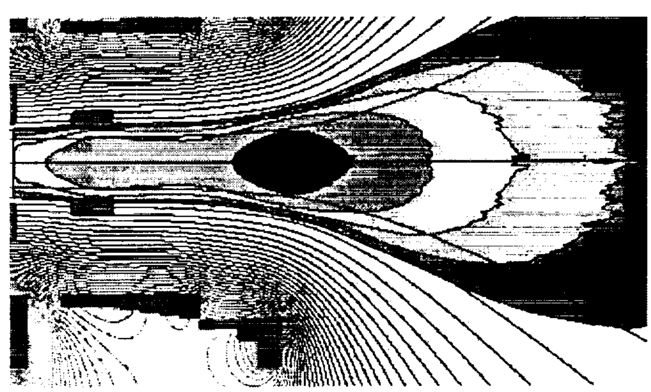
Experiment

Engineering





Theory



TRN-4 Variable Specific Impulse Magnetoplasma Propulsion

Technology Category: Transportation

TRN-4 Variable Specific Impulse Magnetoplasma Propulsion

Background

The Variable Specific Impulse Magnetoplasma Rocket (VASIMR) is an advanced propulsion technology, which has been under development at the NASA Johnson Space Center (JSC) since 1980. Its design addresses the need for faster and more efficient in-space transportation capability than that provided by current chemical rockets. The capability to have rapid and efficient access to all points in our solar system is one of the most compelling reasons for its development.

Project Overview

The VASIMR system is a high power, electrothermal plasma rocket capable of exhaust modulation at constant power. It consists of three major magnetic cells: "forward," "central," and "aft." where plasma is respectively injected, heated and expanded. During operation, neutral gas (typically hydrogen, helium or gas mixtures) is injected at the forward cell and ionized. The resulting plasma is heated with radio frequency (RF) energy in the central cell to the desired temperature and density by the process of ion cyclotron resonance. After heating, the plasma is accelerated in a two-stage magnetic nozzle at the aft cell to provide modulated thrust.

The present research addresses the physics and engineering of the VASIMR in a multifaceted effort addressing the various experimental, theoretical and systems engineering issues. In the experimental area, major advances in plasma generation, solid state RF equipment and high temperature superconducting magnet design have been accomplished. In the theoretical area, the mechanisms for plasma heating, acceleration and detachment at the magnetic nozzle have been demonstrated. Finally, in the systems engineering area, a self-consistent conceptual design of a flight experiment has been completed and has been proposed for flight in 2003. Ongoing studies of the VASIMR will continue to strengthen understanding in these three areas in a brisk effort seeking an early implementation of the technology.

Benefits and Uses

The VASIMR enables rapid and flexible human or robotic interplanetary travel, with greatly improved payload mass fraction over conventional chemical rockets. Its constant power throttling capability enables 90-day Mars transfers and abort capability for human missions. For the commercial sector, VASIMR technology can provide economical access to the Earth-Moon environment, for re-supply, maintenance and repair of telecommunications and remote sensing satellites. The hydrogen propellant and the rocket's magnetic field also provide effective radiation shielding against solar and cosmic radiation. Magnetoplasma technology contributes to important developments in solid state power devices, materials, coatings and magnetic systems using state-of-the-art high temperature superconductors. In its present form, the VASIMR operates as a driven solar or nuclear electric rocket. However, the technology paves the way for future high-power fusion propulsion.

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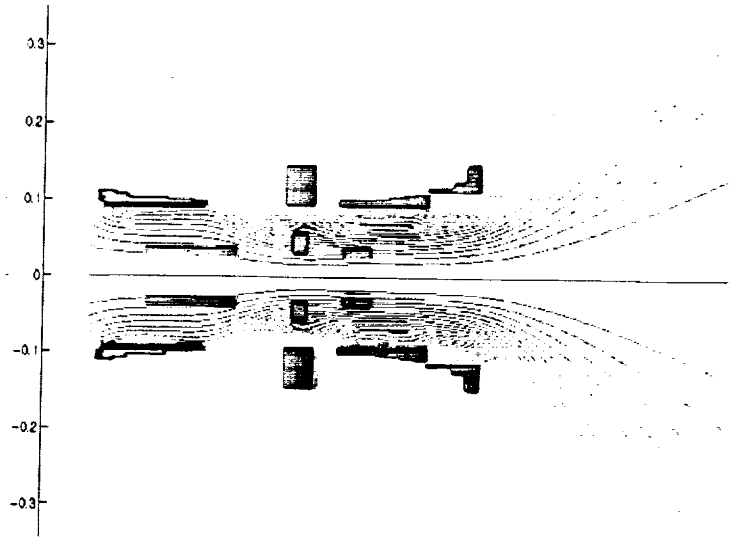
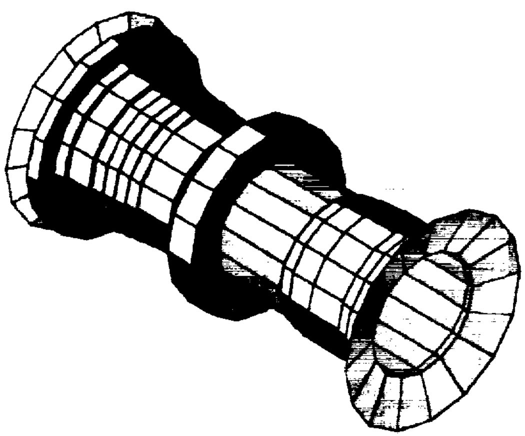
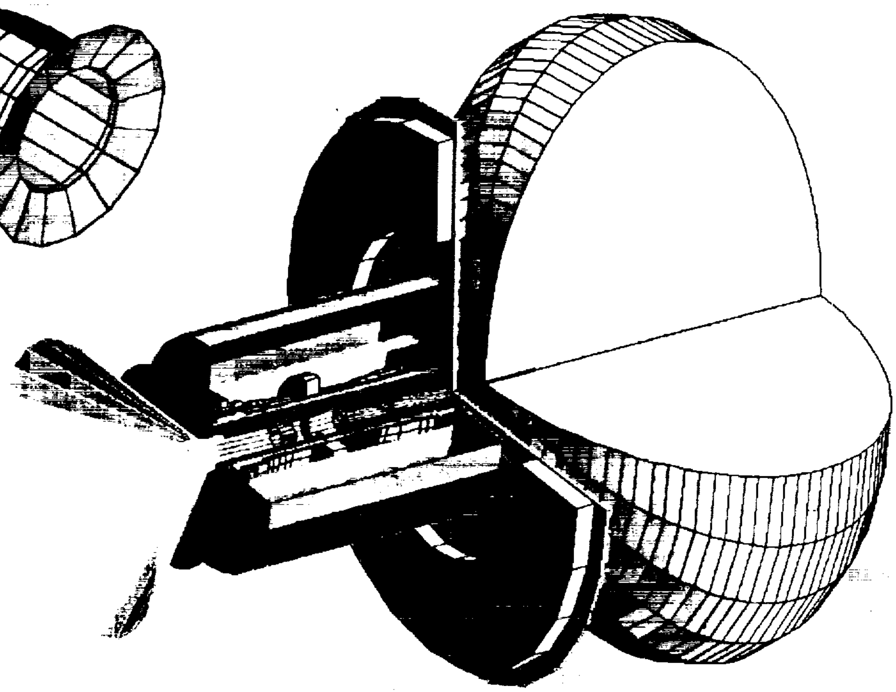
Magnet design for the Radiation and Technology Demonstration Mission.

Clockwise from right: magnetic field map for the RTD VASIMR, conceptual 10kW thruster design, high temperature superconducting magnet spool.







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TRN-5 High Temperature Superconducting Magnets for Space Applications

Background

The development of superconducting technology for space enables a host of important capabilities for commercialization, exploration and research, which are currently beyond reach. Superconductivity has reached a level of maturity, which brings some of these materials out of the research laboratory, and into the realms of technology and manufacturing. Moreover, the natural environment of space may offer favorable thermal control strategies, which make these applications even more attractive.

The Advanced Space Propulsion Laboratory (ASPL) team is engaged in the development of these technologies in support of the Human Exploration and Development of Space enterprise. This effort relates to ongoing activities in both plasma propulsion as well as concepts for magnetic shielding proposed by the ASPL investigators in 1996. In addition, the technology is being developed in support of basic space-borne research in particle physics.

Project Overview

The project goal is to design a full-scale high temperature superconducting magnet prototype as a potential flight component of a 10kW Variable Specific Impulse Magnetoplasma Rocket (VASIMR) propulsion system for the proposed Radiation and Technology Demonstration (RTD) flight. A preliminary design of such a magnet has been completed in collaboration with the Oak Ridge National Laboratory.

The magnet comprises a continuous solenoid in an insulated cylindrical mandrill. The magnet material is 2223 Bismuth Strontium Calcium Copper Oxide (BSCCO) in a silver stabilizing matrix. It operates at a temperature of 35° K with field strength of .7 Tesla at its highest point on axis. The compressive and tensile stresses are well within acceptable limits. Thermal control of the system is accomplished by the supercritical hydrogen propellant for the thruster, as well as multilayer insulation. Construction and ground test of this magnet is expected in late 2000.

Benefits and Uses

Important areas of near-term application include: 1. Magnetoplasma space propulsion. 2. High-energy particle physics. 3. Magnetic shielding of human and robotic spacecraft against high energy charged particles. 4. Energy storage and magnetic actuator devices for space.

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